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Analysis of trace elements and chlorinated hydrocarbons in fish and common mussels from Hardanger Fjord and adjacent fjord areas in fall 1983 and spring 1984

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DIRECTORATE OF FISHERIES

ANALYSIS OF TRACE ELEMENTS AND CHLORINATED HYDROCARBONS IN FISH AND COMMON MUSSELS FROM HARDANGER FJORD AND ADJACENT FJORD AREAS IN FALL 1983 AND SPRING 1984

by

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Bergen, July 1985

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Canada

FOREWORD

As requested by the Directorate of Fisheries in their letter dated 11.05.83, an internal working group of the Directorate implemented a project entitled "Analysis of Trace Elements and Organic Microcontaminants in Fish and the Common Mussel from Hardanger Fjord and the Adjacent Fjord Areas in Fall 1983 and Spring 1984". The group consisted of Bjarne Boe, Central Laboratory; Lars Foyn, Marine Research Institute; and Kaare Julshamn, Nutrition Institute.

The present report also includes results of heavy metal studies on the common mussel from Hardanger Fjord, presented in the 1984 Progress Report "Study of Heavy Metal Contamination of the Common Mussel from Hardanger Fjord and Adjacent Fjord Areas" (Rep. No. 21, Nutrition Institute of the Directorate of Fisheries). The Aquaculture Division (Common Mussel Project) of the Directorate's Marine Research Institute was responsible for planting common mussels in Hardanger Fjord. Terje Kleppe from the Aquaculture Division of the Marine Research Institute is to be thanked for the work he carried out in connection with sampling the mussels.

Karl-Erik Slinning carried the main responsibility in collecting samples and performing trace element analyses of the mussels, while Herborg Haaland was responsible for the trace element studies of fish.

The salaries of the latter two and the sampling expenses were financed through the Norwegian Pollution Monitoring Institute.

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1. SUMMARY AND CONCLUSION (Page 3)

I. Samples of natural common mussels were collected from 36 stations and samples of bred, common mussels were collected from 15 stations (Fig. 1). The samples of the natural common mussel were taken from areas as close as possible to the breeding stations.

It was proposed that cod and flounder be collected. However, it was impossible to catch cod, and the analysis is therefore based on fillets and liver from pollack and flounder from 9 and 10 stations, respectively (Fig. 2). Analyses of trace elements in bred fish (salmon/rainbow trout) from the Hardanger Fjord are also included (Table 6). All values are based on the weight of fresh fish in order to make comparisons possible with regard to concentrations in the consumer product (Tables 1-3). On the other hand, the literature data is often based on dry weight and for this reason the dry content is used in these tables. Salinity and nutrients were measured in water samples from all stations at which the common mussels were collected (Fig. 1).

II. Analyses of polycyclic, aromatic hydrocarbons and chlorinated hydrocarbons showed that neither fish nor common mussels are contaminated by these (Tables 2 and 3).

III. The amounts of arsenic, copper, zinc, cadmium, lead and mercury in the common mussel are reported in figures 3-8 and for fillets and liver of pollack and flounder in the summarizing tables 4 and 5, as well as figures 9-20. The main conclusions regarding trace elements in the common mussel and fish from the Hardanger Fjord and adjacent fjords during 1983 - 1984 is:

- There is a high content of cadmium in the common mussel (≥ 0.5 mgkg^{-1}) in all parts of the Hardanger Fjord.
- There is a high content of mercury in flounder (≥ 0.5 mgkg^{-1}) in all parts of the Sor Fjord.

- When compared with the results from investigations in 1972 and in 1975, one finds there has been little change in the pollution situation. The mercury content in flounder fillets continues to be high even if there was a significant reduction of mercury already in 1973. (Page 4)

IV. Reports on Specific Metals

1. Cadmium

The major part of the Hardanger Fjord down to Valevag is unsuitable for breeding of the common mussel for human consumption. The reason is high cadmium values of over 0.5 $mgkg^{-1}$, fresh weight (Fig. 5). This is a maximum value based on a proposal by the Department of Social Affairs, dated 31 May 1979, regarding the maximum cadmium content in seafood, that is 0.5 $mgkg^{-1}$. Samples from the outer part of the Arkra Fjord (Indre Tungesvik) also had values higher than 0.5 $mgkg^{-1}$, fresh weight, both for natural and bred common mussels. The inner pars of the Akra Fjord had values of some 0.5 $mgkg^{-1}$, fresh weight. Cadmium contents higher than 0.5 $mgkg^{-1}$, fresh weight, indicate that the common mussel samples have been contaminated by industrial pollutants. The health authorities are attempting to limit the cadmium intake as much as possible because of the high biological half-life (20-30 years in liver and kidneys of humans). The large area affected, which stretches to the outer parts of the Hardanger Fjord, is explained by cadmium existing in a dissolved form in the water, and it can therefore be transported over large distances before it is sedimented.

The conditions may improve comparatively quickly if the surface concentration of cadmium is related to runoff from land deposits. However, the situation is serious if the cadmium level in the water is mainly related to leaching from sediments at the bottom of the Sor Fjord. The cadmium content in fish fillets is low and should not cause any health problems. Liver from flounder taken in the Sor Fjord does, however, show high values of cadmium.

Extreme values of 10 $mgkg^{-1}$ were recorded and these are among the highest recorded in the literature.

2. Mercury

An average mercury content of 0.5 $mgkg^{-1}$ was found in flounder fillets in all samples from the Sor Fjord. Further, similar values were found in catches from Haukaneset (Granvin Fjord), at Ulvik (Ulvik Fjord) and at Utne. (Page 5) All these samples had a mercury content of over 0.5 $mgkg^{-1}$. Government health regulations require that average concentrations of mercury exceeding 0.5 $mgkg^{-1}$ be limited in consumption to no more than two meals per week. Accordingly, the liver of flounder should only be eaten occasionally; however, fillets and liver of pollack can be eaten freely. A mercury content of some 1 $mgkg^{-1}$, fresh weight, was established in common mussel samples taken in the inner parts of the Sor Fjord. The results from common mussels show no reduction in the mercury content when compared to 1975. Similarly, there have been no major changes with regard to mercury in flounder during the period 1972 - 1984.

3. Lead

In the inner parts of the Hardanger Fjord lead was the element which increased the most. The values from the outer part of the Hardanger Fjord were less than 2 $mgkg^{-1}$, while values of some 160 $mgkg^{-1}$ were found in the inner parts of the Sor Fjord (Fig. 6). The highest values were found on the west side of the Sor Fjord. The government health authorities' proposal for maximum limits for lead in marine foodstuffs of 5 mg/kg was only met with regard to the common mussel in the outer areas.

The lead content in fillets and liver from pollack and flounder was low, while the content in liver of flounder in the Sor Fjord was high with extreme values exceeding 5 mg/kg.

4. Zinc

The zinc content in the common mussel increased with a factor of 10, from some 10 $mgkg^{-1}$, fresh weight, in Akra Fjord, to 150 $mgkg^{-1}$ in Sor Fjord (Fig. 4). It appears that a saturation of zinc occurs in the common mussel at some 150 $mgkg^{-1}$. These values are significantly lower than those found in bred oysters.

The zinc content in fillets and livers of pollack and flounder on the other hand show a significant increase in the samples from Varaldsoy and Sor Fjord.

5. Arsenic (Page 6)

Arsenic in common mussels varies little; however, arsenic in fillets and liver from flounder caught at Eikhamrane and Krakevikneset show values which are 10 times higher than those found in flounder caught at Grimo and further out in the fjord. In addition, extreme values of over 300 $mgkg^{-1}$, fresh weight, have been found in both muscle and liver. Arsenic occurs naturally, mainly as organic compounds which are assumed to be harmless for humans.

6. Copper

There were only small variations in the investigated samples and the values were within the normal range for the organisms investigated.

V. Farmed fish

Fish farming operations for salmon and trout at Fyksesund and Strandebarm provided very low values, both with regard to fillets and liver for cadmium, lead and mercury. This indicates that the absorption of these metals in salmon-type fish occurs through the food and that very little is absorbed from the water (Table 6).

VI. Future work

All of the investigated area must be considered unsuitable for the breeding of common mussels, since the common mussel from the Hardanger Fjord has cadmium contents higher than those found in the common mussel from unpolluted

areas. We are therefore of the opinion that it is most important that a new investigation be undertaken with regard to the outer part of the Hardanger Fjord for the purpose of establishing a safe outer boundary for the contaminated area.

2. INTRODUCTION AND OBJECTIVES (Page 7)

Various industrial pollutants have been added to the Sor Fjord since 1908. The release of these pollutants has been, and continues to be, of major proportions. Data from 1972 show that the daily discharge then amounted to 6 tons of zinc, 0.3 tons of copper, 30 kg of cadmium, 4.5 tons of lead and 3 kg of mercury. After 1972 these values were reduced, in that a mercury recovery facility was introduced in 1973, and the discharge of waste water and discard acid from the zinc production was reduced during 1975 - 1976. The major contribution comes from suspended jarosite sludge. It contributes the largest amount of metals, at least equal to the previous contributions. The contribution of heavy metals to the fjord system from this waste is calculated to a daily amount of 0.2 - 0.6 tons of arsenic, 2.5 - 5 tons of zinc, 0.2 - 0.49 tons of copper, 19 - 49 kg of cadmium, 1 - 2 tons of lead and 1 - 3 kg of mercury.

The consequences of these metal waste deposits, both in the sea and on land, has been impossible to forecast. However, they have had a signifcant influence on all investigated parts of the marine environment in the Sor Fjord: Fish and Common Mussels (Havre et al., 1973; Stenner and Nickless, 1974; Julshamn, 1981 a, b and 1983; Knutzen, 1983), Seaweeds (Haug et al., 1974; Melhuus et al., 1978; Julshamn, 1981 b; Knutzen, 1982 and 1983), Plancton (Skei et al., 1976, Skei, 1975; Melhuus et al., 1979; Naes and Rygg, 1982), Suspended Particulates (Skei et al., 1973) and Sediments (Skei et al., 1972; NIVA, 1978).

The analysis of cadmium content in the common mussel for the period 1980 - 1983 shows an increase in comparison with the analysis carried out during the period 1973 - 1978 (Knutzen, 1983).

Given the amounts of heavy metal wastes which, over a long time, have been discharged into the sea at the Eitremsneset, and given the propensity of metals to leach from sediments, the areas of the Hardanger Fjord must be affected. This applies particularly to zinc and cadmium dissolved in the sea water as chlorcomplexes which can be transported by the water currents over large distances. The cadmium analyses of the common mussel from the Hardanger Fjord (Page 8) (Strandebarm), Eid Fjord and Granvin Fjord indicate a significantly higher cadmium uptake than compared with common mussels from "clean" waters (Julshamn, 1983 a).

Because of the great interest in establishing breeding of fish and shellfish in the Hardanger Fjord and adjacent fjords, the fisheries authorities found it necessary to undertake a very thorough investigation of heavy metals and organic micropollutants in both fish and shellfish for the whole area.

The objectives of the investigation were thus:

- To investigate which areas of the Hardanger Fjord which are affected to such an extent that commercial breeding of common mussels and fish are inadvisable.
- To investigate what locations should be selected for future monitoring of the pollution developments.

3. SCOPE AND METHODS

3.1 Sampling of common mussels

The common mussel samples were collected during the period 9 - 13 November 1983. Both natural and bred common mussels were collected at the locations shown in Figure 1. A fruitless search for common mussels was also carried out in the Eid Fjord, outside Oksaneset and Kyrkjeteigen (nautical chart 118) and in the Ulvik Fjord, as well as Torevik and Tveito (marine chart 118). The natural mussels at all locations were taken by a diver from rocks at a depth of 1 - 3 m below the low water mark. Bred mussels were collected from a depth of between 1 - 3 m. The water samples for measurement of salinity and nutrients (Page 9)

were taken at the same depths. The mussels were put on ice and transported to the Nutrition Institute of the Directorate of Fisheries for dissection and analyses.

3.2 Sampling of fish

The purpose of the sampling was to comply with the guidelines described in the Oslo and Paris conventions, Joint Monitoring Group (JMG), both with regard to species and number. The fishing was carried out using nets, both for cod and flounder. It was difficult to catch cod and pollack was therefore included. The fish were collected from the locations shown in Figure 2. Specific catch locations, number of fish and dates are provided in the following:

Varaldsoy

A total of 25 pollack and 6 flounder were caught on 9.11.83 and 24.3.84, respectively.

Strandebarm

Twenty-four pollack were caught on 16.11.83. Twelve flounder were caught on 12.11.83 (9) and 21.1.84 (3).

Norheimsund

Twenty-five pollack were caught on 4.11.83. Sixteen flounder were caught on 25.11.83 (7), 24.1.84 (5) and 28.1.84 (4).

Herand

Twenty-one pollack were caught on 26.11.83. Fifteen flounder were caught on 26.11.83 (4), 6.12.83 (6), 5.1.84 (2) and 17.1.84 (3).

Haukaneset, Granvin Fjord (Page 10)

Fourteen pollack and 7 flounder were caught on 19.3.84.

Ulvik

Three flounder were caught on 25.3.84.

Utne

Twenty pollack were caught on 20.1.84. Six flounder were caught on 30.11.83 (2), 3.12.83 (2) and 22.12.83 (2).

Grimo

Nineteen pollack and two flounder were caught on 11.3.84.

Eikhamrane

Twelve pollack and 13 flounder were caught on 15.2.84.

Krakevikneset

No pollack were caught. Twenty-two flounder were caught on 17.3.84.

All fish were frozen and then sent to the Nutrition Institute of the Directorate of Fisheries for dissection and analyses.

3.3 Processing of samples

Common mussel

The mussels were measured, dissected, weighed and classified in groups as shown in Table 1 of the appendix. The samples were then freeze-dried (Page 11) to a constant weight and homogenized. Some of the dry matter was sent to the Central Laboratory of the Directorate of Fisheries for analysis of chlorinated hydrocarbons and PAH.

Fish

Otoliths were removed and sent to the Marine Research Institute for age determination. The sex of the fish was determined and the development of the male ovaries was recorded. Samples of the dorsal muscle were removed in a standardized fashion. The muscle samples were homogenized, freeze-dried, dried to a constant weight and homogenized. The samples were sealed in glass until analysis. The liver was removed, weighed and homogenized. Flounder livers were freeze-dried, while pollack livers were stored frozen until analysis. All the samples were sent to the Central Laboratory of the Directorate of Fisheries for analysis of organic micropollutants.

3.4 Methods of analysis

3.4.1 Polycyclic, aromatic compounds

A freeze-dried sample of about 1 g, equivalent to about 5 g fresh weight, was carefully weighed and boiled for 3 hours in a 25 ml saponification reactant. The latter comprised 30 ml methanol and 5 ml KOH-solution (24 g KOH + 20 ml water). After cooling, the non-saponified matter was extracted in pentane (3 x 15 ml) and the pentane was vapourized to some 0.5 ml in a helium flow. The extract was then placed on a 1 g silica-column (70-230 mesh) and was elutriated with 10 ml pentane. To the elutriate was added a known amount of fluorene equivalent to 50-100 ng/g of sample.

A microlitre of the sample was injected at 40° in a GC/MS-instrument and the temperature raised to 280° at 8°/min. A 50 m x 0.2 mm i.d. HP quartz column with 5% phenylmethylsilicon was used. The mass spectrometre functioned as a selective detector in which the selected m/z-values corresponded to the molecular mass of the PAH compounds in question.

The following mass-values were used: 128, 141, 142, 156, 170, 178, (Page 12) 184, 191, 192, 198, 202, 206, 212, 226, 228, 252 and 276.

The quantity of individual compounds was calculated on the basis of previously determined calibration factors using fluorene as an inner standard.

3.4.2 Organic chloride compounds

To a sample of 0.14 g was added 10 ml hexane isopropanol 1:1. The mixture was homogenized in a crusher and then spun in a centrifuge. The hexane isopropanol-phase was then transferred to a test tube. The homogenate was extracted with 10 ml hexane/isopropanol and the extract washed twice with 5-10 ml water. The hexane phase was removed and concentrated to about 2 ml in a nitrogen flow and 2 ml of concentrated sulphuric acid was added. After stirring and settling for 30 minutes the samples were spun in a centrifuge. The hexane phase was transferred to a test tube and the remaining sulphuric acid was further twice extracted with hexane. The samples were then vapourized to about 1 ml and 1 µl

was injected in a 25 m x 0.2 mm i.d. HP quartz column coated with methylsilicon. The samples were analysed twice, the second time after addition of a known amount of DDE as an internal standard. An electron capture device was used for this purpose.

3.4.3 Trace element analyses

Prior to analyses for copper (Cu), zinc (Zn), arsenic (As), cadmium (Cd), lead (Pb) and mercury (Hg), the samples were treated with acid. Copper and zinc were analysed by means of flame atomic absorption. The elements As, Cd and Pb were determined by graphitizing furnace atomic absorption, while Hg was determined by cold vapour atomic absorption. $(NH_4)_2HPO_4$ was used as a matrix modifying agent in the determination of lead, while an Ni-solution was used as a temperature stabilizer during the determination of arsenic (As) (Julshamn and Braekkan, 1975; Egaas and Julshamn, 1978; Julshamn et al., 1981).

Table 1. Mean values and relative standard deviations (%) of trace element contents ($mgkg^{-1}$) dry substance in three biological samples, based on data from ICE's ~~Circular~~ Round test 3 in which the Nutrition Institute of the Directorate of Fisheries (FE) participated.

Tabell 1. Middelverdi og relativ standardavvik (%) (gitt i parentes) av sporelementinnholdet ($mgkg^{-1}$ tørt materiale) i tre biologiske prøver basert på data fra ICES's ringtest hvor Fiskeridirektoratets Ernæringsinstitutt (FE) var deltager.

Sample	Cu		Zn		As		Cd		Pb		Hg	
	ICES	FE	ICES	FE	ICES	FE	ICES	FE	ICES	FE	ICES	FE
A[a)]	331(10)	332(0.7)	179(6)	179(4)	25(21)	29.8(7)	26(8)	33(10)	5.57(30)	7.94(14)	0.254(19)	0.263(2)
B[b)]	3.7(16)	3.25(17)	58(5)	58.7(2)	7.1(29)	7.3(9)	0.75(13)	0.83(11)	0.29(41)	0.28(26)	0.081(10)	0.075(11)
C[c)]	3.1(27)	3.12(30)	93(10)	99.1(3)	4.6(35)	1.1(22)	0.06(38)	0.06(14)	1.98(41)	1.43(22)	0.056(16)	0.058(9)

a) hummer hepatopankreas
b) kamskjell muskel
c) rødspette

a) lobster hepatopancreas
b) scallop muscle
c) plaice

The accuracy of the element determinations was established by (Page 14) comparison with the standard references from NBS and by participation in round intercalibration tests arranged by the International Council for the Exploration of the Sea (ICES) in December 1983. Some of these results are presented in table 1. Fiffy-one laboratories from sixteen different countries participated. The samples which were analysed in this round of tests had various marine origins and therefore also various metal content (Berman, 1984). The accuracy for the six trace elements which were analysed is considered good. The accuracy was determined by comparing our values with the mean values from other participating laboratories (table 1). In this case the accuracy is the percentage spread of five parallel analyses giving rise to a relative standard deviation (table 1).

4. RESULTS AND DISCUSSION

The results from analysis of PAH in flounder muscle are presented in table 2 and those of hexachlorbenzene in pollack liver are presented in table 3. Table 1 of the appendix presents the values for arsenic, copper, zinc, cadmium, lead and mercury in common mussels. The trace element content of individual samples from pollack fillets and liver are presented in table 2 of the appendix, while the corresponding content in flounder is presented in table 3 of the appendix.

For both natural and bred common mussels the concentration of trace elements at the various locations are presented as bars in figures 3-8. Mean values and range of distribution in pollack fillets and liver are shown in table 4, while corresponding results for flounder are shown in table 5. As well, bars are used to present mean values in figures 9-20.

4.1 PAH and chlorinated hydrocarbons

Polycyclic, aromatic hydrocarbons (PAH) were found in small amounts in samples of flounder caught in the Sor Fjord.

TABLE 2. Analysis of PAH[a)] in flounder muscle (mg/kg freeze-dried sample)

Tabell 2. Analyse av PAH[a)] i flyndre-muskel (mg/kg frysetørket prøve).

PAH	Kråkevikneset	Eikhamrane
Naphthalene	2.9	1.5
Me-naphthalene	8.6	6.2
Di-Me-naphthalene	19	11
Tri-Me-naphthalene	22	9.2
Phenanthrene	20	14
Me-phenanthrene	4.3	3.5
Di-Me-phenanthrene	1.3	6.5
Dibenzothiophene	6.5	1.o
Me-dibenzothiophene	2.2	1.4
Di-Me-dibenzothiophene	2.2	2.8
Tri-Me-dibenzothiophene	4.3	4.0
Fluoranthene	0.9	0
Pyrene	0.9	0

a) Følgende forbindelser ble ikke påvist over deteksjonsgrensen 0.1 mg/kg: fluorene - anthracene - Me-pyrene - benzo(e)phenanthrene - chrysene - naphthacene - benzofluoranthene - benzopyrene - perylene - benzo(ghi) perylene.

a) The following compounds were not found with a detection limit of 0.1 mg/kg: fluorene - anthracene - Me-pyrene - benzo(e)phenanthrene - chrysene - naphthacene - benzofluoranthene - benzopyrene - perylene - benzo(ghi)perylene.

TABLE 3: Analysis of hexachlorbenzene in four pollack livers[a] (Mg/kg freeze-dried sample)

Tabell 3. Analyse av heksaklorbenzen i fire seilever[a] (mg/kg frysetørket prøve).

Lokalitet	1	2	3	4
Varaldsøy	0.02	0.06	0.03	0.02
Strandebarm	0.03	0.02	0.02	0.03

[a] Tilsvarende lave konsentrasjoner ble påvist i prøver fra: Haukaneset - Grimo - Eikhamrane - Herand og Utne. Alle blåskjellprøver og prøver av fiske-filet var negative. Dette gjaldt prøver av: Seifilet fra Strandebarm og Herand, flyndrefilet fra Kråkevikneset og Eikhamrane og blåskjell fra samtlige lokaliteter (Fig. 1 og 2).

[a] Related low concentrations were found in samples from: Haukaneset - Grimo - Eikhamrane - Herand and Utne. All common mussel samples and samples of fish fillets were negative. This applied to samples of pollack fillets from Strandebarm and Herand, flounder fillet from Krakevikneset and Eikhamrane, as well as common mussels from all locations (figures 1 and 2).

The results from the PAH analyses are presented in table 2 with regard to the freeze-dried samples. These values are much lower than what can be found in various smoked fish products. In particular, complex compounds with 4 to 6 rings have been in the spotlight due to their carcinogenic effect. Such compounds could not be found in any of the analysed samples.

No PAH compounds were found in the samples from pollack and the common mussel.

With regard to chlorinated hydrocarbons, such compounds were only found in trace amounts in a few samples of pollack livers. No chlorinated compounds could be found in the other fish samples nor in the common mussels. Table 2 presents the results for hexachlorbenzene which is the chlorinated compound found to the greatest extent. The established amount is equivalent to approximately 1% of what is found in pollack liver from Frier Fjord and is of no consequence with regard to fish consumption.

Thus, the analysis of polycyclic, aromatic hydrocarbons and chlorinated hydrocarbons showed that neither fish nor common mussels were contaminated by these compounds.

4.2 Arsenic

4.2.1 Common mussel (Fig. 3)

The arsenic content ranged from 0.8 to 2.2 mg/kg. There was no increase in the values as one proceeded from the outer parts of the Hardanger Fjord towards the discharge location. The result is comparable with the previous results from unpolluted areas (Julshamn, 1981 a). As well, there is no difference between natural and bred common mussels.

4.2.2 Pollack (Table 4, Fig. 9)

The arsenic content in pollack fillets ranges from 1.1 to 3.5 mg/kg, with mean values ranging from 1.6 to 2.8 mg/kg in the outer areas of the Hardanger Fjord. The arsenic content in liver is some 2 to 3 times higher than in the fillets.

Table 4. Mean concentration and distribution of arsenic, copper, zinc, cadmium, lead and mercury in pollack from the Hardanger and adjacent fjords. (The values are based on fresh weight; the number is shown in parenthesis; F = fillet and L = liver).

Tabell 4. Gjennomsnittskonsentrasjon og spredning for arsen, kobber, sink, kadmium, bly og kvikksølv i sei fra Hardangerfjorden og tilstøtende fjorder. (Verdiene er basert på frisk vekt; antall i parentes; F=filet og L=lever).

Location	Sample	Length (cm)	Weight (kg)	Dry Substance gkg^{-1}	As $mgkg^{-1}$	Cu $mgkg^{-1}$	Zn $mgkg^{-1}$	Cd μgkg^{-1}	Pb $mgkg^{-1}$	Hg μgkg^{-1}
Varaldsøy	F	50.8 48-52	1.31 1.2-1.5	223 211-227	2.8(10) 2.1-3.4	0.86(10) 0.81-0.88	4.3(10) 3.9- 4.7	5.9(10) 4.0-9.5	0.06(10) 0.02-0.14	100(10) 85-110
	L				5.0(10) 3.3-6.7	6.1(10) 4.2 -7.8	16.9(10) 13.3-21.5	92(10) 56-148	(10) <0.05-0.20	42(10) 23-69
Strandebarm	F	51.1 43-57	1.45 0.9-1.9	229 223-236	1.6(10) 1.1-2.3	0.65(10) 0.57-0.70	4.6(10) 3.7-5.1	4.1(10) 3.0-6.6	0.05(10) 0.02-0.19	93(11) 71-120
	L				4.0(10) 2.6-5.5	4.6(11) 1.8-5.8	15.9(11) 11.2-21.8	81(11) 32-152	(11) <0.05-0.20	53(11) 31-69
Norheimsund	F	53.2 47-68	1.77 1.4-3.0	221 220-227	1.6(10) 1.1-2.1	0.86(10) 0.85-0.89	4.3(10) 3.1-5.1	4.4(10) 2.9-5.4	0.06(10) 0.05-0.08	110(10) 95-140
	L				4.3(9) 2.9-7.3	2.9(10) 2.3-3.5	10.7(10) 9.2-13.1	58(9) 33-86	(9) <0.05-0.07	57(10) 43-65
Herand	F	52.7 48-60	1.55 1.1-2.3	225 222-234	2.3(10) 1.5-3.5	0.88(10) 0.85-0.92	4.9(10) 3.8-5.8	4.8(10) 1.6-9.1	0.03(10) 0.05-0.08	100(10) 82-130
	L				7.1(10) 3.1-14.7	4.1(10) 1.7-5.6	17.9(10) 14.0-22.0	101(10) 70-138	(10) <0.05-0.12	53(10) 32-71

Table 4. Mean concentration and distribution of arsenic, copper, zinc, cadmium, lead and mercury in pollack from the Hardanger and adjacent fjords (cont.).

Tabell 4. Gjennomsnittskonsentrasjon og spredning for arsen, kobber, sink, kadmium, bly og kvikksølv i sei fra Hardangerfjorden og tilstøtende fjorder. (forts.)

Location	Sample	Length (cm)	Weight (kg)	Dry Substance gkg^{-1}	As $mgkg^{-1}$	Cu $mgkg^{-1}$	Zn $mgkg^{-1}$	Cd μgkg^{-1}	Pb $mgkg^{-1}$	Hg μgkg^{-1}
Haukaneset	F	70.2	2.7	199	3.5(10)	0.78(10)	3.7(10)	4.2(10)	0.04(10)	180(12)
		60-80	1.5-3.7	190-210	1.5-6.8	0.69-1.0	3.4-4.5	1.5-9.2	0.01-0.20	82-220
	L				13.0(12)	8.6/12)	21.4(12)	198(11)	0.13(12)	91(12)
					3.3-47.9	1.8-16.4	13.4-42.4	87-373	0.05-0.18	54-170
Utne	F	58.2	1.91	223	4.8(19)	0.80(19)	4.0(19)	4.4(18)	0.03(19)	110(19)
		53-65	1.3-2.8	212-240	3.6-6.4	0.72-1.1	3.5-5.3	1.6-9.2	0.02-0.11	75-140
	L				8.2(20)	5.8(20)	16.4(20)	90(20)	(20)	37(20)
					5.7-16.0	3.7-10.9	13.0-22.9	59-150	<0.05-0.29	23-110
Grimo	F	59.4	2.00	214	9.8(19)	0.78(19)	4.2(19)	3.9(19)	0.02(19)	120(19)
		52-70	1.2-2.8	204-222	4.6-13.5	0.66-0.99	3.8-4.7	1.0-9.4	0.01-0.05	79-170
	L				23(19)	4.5(19)	21.4(19)	170(19)	0.07(19)	64(16)
					6.0-60.0	2.9-6.6	14.1-35.2	33-441	0.05-0.18	51-88
Eikhamrane	F	54.8	1.61	211	9.4(12)	0.78(12)	4.7(12)	3.3(12)	0.03(12)	110(12)
		43-59	0.8-1.9	204-221	4.9-13.3	0.69-1.2	4.3-5.4	1:0-5.2	0.01-0.20	82-140
	L				26.0(12)	4.6(12)	23.8(12)	220(12)	0.07(12)	72(12)
					6.0-45.0	2.5-6.9	11.4-36.4	65-330	0.05-0.18	27-140

The Granvin Fjord has mean values higher than the outer areas of the (Page 20) Hardanger Fjord. In particular, pollack livers showed great variations in concentration with extreme values of 48 mg/kg.

The arsenic content, both in pollack fillets and liver, increased by a factor of 5 to 6 when comparing the locations in the Hardanger Fjord with Grimo and Eikhamrane in the Sor Fjord.

The arsenic content in pollack from the outer areas of the Hardanger Fjord differs only little from the content found in pollack from the North Sea (Julshamn, 1978). On the other hand, the arsenic content in this investigation showed greater variations and also a higher mean than a Scottish investigation carried out by Falconer, et. al in 1983. In comparison with other species the mean values for pollack are comparatively low and do not vary as much.

Experience indicates that the arsenic content in pollack is not a problem since the FAO/WHO-expert group of 1967 recommended a maximum acceptable daily intake of 3.5 mg As/day/adult. Thus, a meal of some 200 g would not exceed the limit value.

4.2.3 Flounder (Table 5, Fig. 10)

The arsenic content in both flounder fillets and flounder liver is high in comparison with pollack. This applies to all the investigated locations. The average value for flounder fillets varied from 9 to 28.2 mg/kg in the fjord area, with the exception of the innermost locations in Sor Fjord, which had variations ranging from 1.4 to 69.6 mg/kg. The arsenic content in flounder fillets from the two innermost locations showed high extreme values and therefore also high mean values. Several flounder were found having an arsenic content of over 100 mg/kg with regard to both fillets and liver. The highest recorded value was a flounder of 310 g from Krakevikneset having an arsenic content of 311 and 425 mg/kg for fillets and liver, respectively. As far as we know this is the highest recorded arsenic content reported in the literature for flounder.

Table 5. Mean concentrations and range of distribution for arsenic, copper, zinc, cadmium, lead and mercury in flounder from the Hardanger Fjord and adjacent fjords (the values are based on fresh weight; the number is in parenthesis; F = fillet and L = liver).

Tabell 5. Gjennomsnittskonsentrasjon og spredning for arsen, kobber, sink, kadmium, bly og kvikksølv i flyndre fra Hardangerfjorden og tilstøtende fjorder. (Verdiene er basert på frisk vekt; antall i parentes; F=filet og L=lever.)

Location	Sample	Length (cm)	Weight (kg)	Dry Substance gkg^{-1}	As $mgkg^{-1}$	Cu $mgkg^{-1}$	Zn $mgkg^{-1}$	Cd μgkg^{-1}	Pb $mgkg^{-1}$	Hg $mgkg^{-1}$
Varaldsøy	F	36.5 30-42	383 250-500	226 215-244	17.5(6) 10.8-31.8	<0.10(6)	3.7(6) 3.4-4.2	<0.5(6)	0.06(6) 0.01-0.14	0.29(5) 0.19-0.55
	L			420 367-494	14.4(5) 8.4-24.6	3.4(5) 0.79-10.2	32.2(5) 10.5-59.2	228(5) 136-381	0.06(5) 0.02-0.20	0.34(5) 0.11-0.72
Strandebarm	F	39.3 30-48	498 200-750	217 201-228	10.2(10) 4.3-25.2	<0.10(10)	3.4(10) 2.4-4.4	<0.5(10)	0.03(10) 0.02-0.10	0.28(12) 0.08-0.66
	L			447 273-557	11.6(9) 5.2-32.8	7.1(9) 3.5-13.6	68.7(9) 48.7-95.5	103(9) 52-237	0.25(9) 0.09-0.47	0.30(9) 0.08-0.91
Norheimsund	F	38.2 30-50	486 250-1150	207 171-233	16.8(10) 5.8-61.7	<0.10(10)	3.5(10) 2.9-4.1	1.9(10) 0.5-16.8	0.04(10) 0.01-0.21	0.37(16) 0.06-0.83
	L			491 242-799	14.5(10) 5.2-35.0	13.5(10) 1.3-39.4	77.3(10) 30.1-136	464(10) 115-2460	0.84(10) 0.08-7.5	1.1(14) 0.13-5.1
Herand	F	37.7 28-50	503 300-1100	216 193-295	10.1(10) 5.5-24.7	0.29(10) 0.10-0.69	3.9(10) 3.1-5.3	1.0(10) 0.5-3.6	0.03(10) 0.01-0.07	0.32(15) 0.07-0.77
	L			416 277-56	7.5(10) 2.1-13.3	10.6(10) 0.82-29.3	60.2(10) 30.1-99.1	236(10) 64-790	0.19(10) 0.05-1.3	0.28(15) 0.03-0.52

Table 5. Mean concentrations and range of distribution for arsenic, copper, zinc, cadmium, lead and mercury in flounder from the Hardanger Fjord and adjacent fjords (cont.).

Tabell 5. Gjennomsnittskonsentrasjon og spredning for arsen, kobber, sink, kadmium, bly og kvikksølv i flyndre fra Hardangerfjorden og tilstøtende fjorder. (forts.)

Location	Sample	Length (cm)	Weight (kg)	Dry Substance gkg^{-1}	As $mgkg^{-1}$	Cu $mgkg^{-1}$	Zn $mgkg^{-1}$	Cd μgkg^{-1}	Pb $mgkg^{-1}$	Hg $mgkg^{-1}$
aukaneset	F	31.4 23-40	255 81-451	203 189-216	28.2(7) 5.4-69.6	0.24(7) 0.21-0.24	5.5(7) 2.7-7.1	6.2(7) 0.5-24.9	0.05(7) 0.01-0.12	0.60(7) 0.06-1.3
	L			280 249-351	19.9(7) 6.6-41.5	16.0(7) 3.3-37.5	59.4(7) 47.1-76.5	1750(7) 282-4960	0.70(7) 0.09-1.2	0.84(7) 0.10-1.2
lvik	F	25 20-28	177 150-200	183 164-195	21.9(3) 4.0-31.7	0.54(3) 0.21-0.66	4.2(3) 3.2-6.0	0.8(3) 0.5-1.3	0.03(3) 0.02-0.07	0.36(3) 0.13-0.77
	L			298 242-410	14(3) 5.8-22.5	15.2(3) 6.2-37.4	40.0(3) 26-54.8	455(3) 300-530	1.7(3) 0.41-2.5	
tne	F	40.0 33-46	533 200-800	199 182-212	9.6(6) 1.4-29.5	0.48(6) 0.20-0.73	4.6(6) 3.6-6.4	1.3(6) 0.5-4.3	0.02(6) 0.01-0.02	0.55(6) 0.25-1.2
	L			343 222-442	18.4(5) 4.8-53.3	16.7(5) 4.9-24.8	69.8(5) 45.3-84.6	310(5) 164-545	0.11(5) 0.02-0.18	1.0(4) 0.16-2.6

Table 5. Mean concentrations and range of distribution for arsenic, copper, zinc, cadmium, lead and mercury in flounder from the Hardanger Fjord and adjacent fjords (cont.).

Tabell 5. Gjennomsnittskonsentrasjon og spredning for arsen, kobber, sink, kadmium, bly og kvikksølv i flyndre fra Hardangerfjorden og tilstøtende fjorder. (forts.)

Location	Sample	Length (cm)	Weight (kg)	Dry Substance gkg^{-1}	As $mgkg^{-1}$	Cu $mgkg^{-1}$	Zn $mgkg^{-1}$	Cd μgkg^{-1}	Pb $mgkg^{-1}$	Hg $mgkg^{-1}$
Grimo	F	39.0 45-33	475 330-620	200 184-216	9.0(2) 4.3-13.7	0.23(2) 0.16-0.30	3.4(2) 3.0-3.8	1.9(2) 1.8-1.9	0.02(2) 0.01-0.04	0.51(2) 0.35-0.67
	L			364 252-475	7.1(2) 4.1-10.1	5.7(2) 5.5-5.9	61.2(2) 48.1-74.3	200(2) 60-340	0.28(2) 0.10-0.47	1.7(2) 0.40-3.1
Eikhamrane	F	33.6 30-40	389 180-550	185 157-217	66.0(13) 4.7-235	0.41(13) 0.19-0.70	3.7(13) 2.9-4.9	3.4(13) 0.5-10.9	0.15(13) 0.01-0.51	0.47(13) 0.06-1.3
	L			326 227-481	46.4(9) 1.3-185	7.9(9) 3.1-22.8	48.1(9) 25.6-85.3	2590(9) 200-10500	3.4(9) 0.47-5.6	3.2(9) 0.06-13.7
Kråkevikneset	F	30.8 23-47	329 107-655	191 168-216	51.4(22) 2.9-311	0.22(22) 0.17-0.48	5.0(22) 2.5-15.3	6.2(22) 0.5-46.7	0.11(22) 0.01-0.59	0.51(22) 0.03-2.4
	L			240 100-405	96(10) 3.4-425	7.1(10) 0.88-15.4	38.7(10) 11.7-80.8	1080(10) 826-3230	2.6(10) 0.08-7.2	2.4(10) 0.07-50.7

The arsenic content in the liver is roughly on the same level as in the fillet (Page 24) or perhaps slightly less, with the exception of flounder, which provided extremely high arsenic content, with the liver values being the highest.

Several other investigations have been carried out with regard to the arsenic content in flounder; for instance, a Danish investigation of plaice from the North Sea. That investigation shows a range from 3.9 to 22 mg/kg with a mean content of 1.2 mg/kg (Andersen, 1982). In this study it was found that the liver value was three time less than the fillet value. An English investigation of trace elements in fish and shellfish landed in Scotland showed high arsenic content in plaice. The content varied from 1.0 to 90 mg/kg, with a mean of 13.7 mg/kg.

The arsenic content in flounder fillets from the Hardanger Fjord is not much different from that of plaice in the North Sea, even if these species are different. The very wide range of distribution found in the inner parts of the Sor Fjord must be seen in the light of the jarosite sludge which contains significant amounts of arsenic.

The arsenic content in fish generally seems to mirror the arsenic content in the food of the fish. The species related differences between pollack and flounder is therefore dependent on different nutritional intakes. Food hygienic considerations are based on the extent of the part of the arsenic content which can be attributed to poisonous, inorganic compounds. (Lunde 1977) claims that only 5 - 15% of the arsenic compound in marine organisms can be extracted in sulphuric acid extraction, while the remainder constitutes organically bound compounds of low molecular weight. These organic compounds are harmless to humans (Nordberg et al., 1979), since they are quickly absorbed in the urine (Westoo and Rydalv, 1972). This may apply to flounder having an arsenic content less than 100 mg/kg. However, fish with extreme values require a most thorough investigation so that it can be determined what form of arsenic (Page 25) is prevalent in the fish.

4.3 Copper

4.3.1 Common mussel (Fig. 4)

The copper content in the common mussel ranged from 0.3 to 2.5 mg/kg, having a mean content of some 1 mg/kg. Only small differences were found in the copper content between samples caught in the outer parts of the Hardanger Fjord and in the Sor Fjord. Nor was there any difference between natural and bred common mussels. Previous investigations of copper in the common mussel from the Hardanger Fjord/Sor Fjord provided comparable results with regard to copper (Stenner and Nickless, 1974; Julshamn, 1981 b). The copper content in the common mussel does not well reflect the copper level in sea water. The reason may be that the common mussel has the ability to separate the copper very effectively. Phillips (1976) has suggested a special transport mechanism across the gills for copper. The copper content in the common mussel does not appear to be a health problem.

4.3.2 Pollack (Table 4, Fig. 11)

The copper content in pollack fillets varied somewhat between fish from the same location, as well as between fish from various locations. The mean content over the various locations ranged from 0.65 to 0.86 mg/kg, with a total distribution between 0.57 and 1.2 mg/kg. Even at relatively low copper concentrations in fish fillets, there are species variations in fish. Pollack is among the fish species having the highest copper content.

Previous investigations of trace elements in fish from the North Sea indicate a mean copper content of 0.8 mg/kg (Julshamn et al., 1978). This correlates with the results from this investigation. The copper content in pollack liver is some 5 - 6 times higher than in the fillets. No geographic variations were found with regard to fillets.

4.3.3 Flounder (Table 5, Fig. 12)

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The copper content in flounder fillets varied from <0.10 to 0.73 mg/kg with a mean content range from <0.10 to 0.54 mg/kg depending on

location. As indicated in table 3, the lowest values were found at the outermost locations. The low copper content in the flounder fillets seems to be species dependent (Andersen, 1982). The copper content in flounder liver was 20 - 50 times higher than in the fillets and varied greatly. The highest mean content was found in fish from Ulvik and Utne and not from the locations in the inner part of the Sor Fjord. The copper content in flounder liver from Varaldsoy and Strandebarm is of the same level as that found in flounder from the North Sea (Andersen, 1982).

4.4 Zinc

4.4.1 Common mussel (Fig. 5)

The zinc content in common mussels from "unpolluted" waters is within the range of 8 - 18 mg/kg of fresh weight. This range is somewhat diffused since there are extreme values which are higher (Julshamn, 1981 c). The results for zinc in this study showed slight traces of the element already in the outermost areas of the Hardanger Fjord (one case). The zinc increased evenly as one progressed up the Hardanger Fjord; however, the zinc content in the common mussel from the Sor Fjord appears to have reached a maximum, or saturation level.

Throughout, the values are higher in natural common mussels than in bred common mussels.

The maximum values in this investigation are lower than those that were reported by NIVA, 1983. This difference can be explained by differences in size and age of the mussels, but also by the difference in season and location. An indication of saturation of zinc content in the common mussel is reported by Phillips (1977). He postulated an asymptote for the maximum uptake in the common mussel. For this reason the zinc uptake in the common mussel should be related to the zinc level in the water, at low concentrations.

4.4.2 Pollack (Table 4, Fig. 13) (Page 27

There were no geographic variations with regard to the zinc content in pollack fillets. The content varied very little, from 3.1 to 5.8 mg/kg.

These levels have been previously found in various fish species of the North Sea. No major spread in the distribution was found for the pollack liver. The zinc content in the pollack liver is some 2 to 5 times higher than in the fillet.

4.4.3 Flounder (Table 5, Fig. 14)

The zinc content in the flounder fillet was similar to that of pollack. The greatest range was found in flounder from Krakevikneset, these varying from 2.5 to 15.3 mg/kg. Other variations with regard to the flounder fillets were small.

On the other hand, the zinc content in the liver varied greatly with values from 10.5 (Varaldsoy) to 136 mg/kg (Norheimsund). There were no geographic variations. Further, there was no positive correlation between the zinc content in the fillets and in the liver. The zinc content in plaice from the North Sea is only about half of the values established in this investigation.

4.5 Cadmium (Fig. 6)

4.5.1 Common mussel

The concentration of cadmium in the common mussel from the outermost areas of the Hardanger Fjord was some 1 $mgkg^{-1}$, fresh weight. This increased to 20 $mgkg^{-1}$ in the inner areas of the Sor Fjord. Values lower than 0.5 $mgkg^{-1}$ were only found in bred mussels from Akra Fjord and some natural mussels from the same area. This means that the cadmium affected area includes all of the Hardanger Fjord. The cadmium content in the common mussel from Strandebarm was higher in this investigation than in samples taken in 1982. Typical values that year were some 3 $mgkg^{-1}$, fresh weight. The cause of the cadmium pollution appears evident; zinc refinement operations in the inner areas of Sor Fjord. Values exceeding 0.5 $mgkg^{-1}$ can also be explained by industrial metal pollution since the cadmium content in the common mussel from "clean" water ranges from 0.1 - 0.4 $mgkg^{-1}$, fresh weight (Julshamn, 1981 c, 1982 b). Even if the metal

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discharge has been reduced somewhat during the last decade, the concentrations in the common mussel have increased in the Sor Fjord during the period 1975 - 1983. This is confirmed both by data here reported and by data from NIVA, 1983 as well as Julshamn, 1983. The increase is explained by an increased contribution through runoffs from land deposits of waste (NIVA, 1983). If this is the case, the conditions in the outer fjord areas can quickly be improved if the runoff from these land deposits is stopped.

The reason for the wide range of distribution which we found in the Hardanger Fjord may be that the cadmium is mainly dissolved in the water. This would indicate that cadmium can easily be transported by the water over long distances. This also means that the pollution must have been going on for a long time. Cadmium is the element which causes the greatest health problems in the common mussel. The health authorities are attempting to limit the intake of cadmium as much as possible and in that regard proposed to the Department of Social Affairs that a maximum limit for shellfish of 0.5 $mgkg^{-1}$ be introduced. However, this measure has not yet been taken. The reason for the comparatively stringent limit proposed is the high biological half-life of cadmium in human organs (20 - 30 years in liver and kidneys).

4.5.2 Pollack

The cadmium content in pollack fillets varied between 1.0 and 9.5 µg/kg. No geographic differences were found. The content in the pollack fillets from the Hardanger Fjord appears to be no different from the cadmium content in pollack, cod and herring from the North Sea (Andersen, 1982). However, variations in sampling and methods of analyses may play a part.

The cadmium content in pollack liver increased by a factor of from 2 to 4 between Norheimsund and Grimo/Eikhamrane. The highest values were found in the pollack liver from Grimo (0.44 mg/kg). The normal values for cadmium content in pollack liver seems to vary between 5.0 to 150 µg/kg (Boe et al., 1978).

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On the basis of a general limit of 0.5 mg/kg in marine food products consumption of this fish should, with regard to cadmium, not cause any health problems. This is also indicated by the FAO/WHO's acceptable weekly intake of 400 - 500 µg per person; equivalent to a daily intake of 70 µg.

4.5.3 Flounder

The flounder fillet content tended to be lower than that of pollack. A cadmium content of less than 1 µg/kg was found in fish from Strandebarm and Varaldsoy, while a mean content of 6.2 mg/kg was found in flounder from Krakevikneset. Extreme values of 46.7 and 24.9 mg/kg were found in fillets from Krakevikneset and Haukaneset. The cadmium content in the flounder fillets is compatible with what has been reported by the Environmental Protection Committee, Odda, 1972. There are significant variations in the cadmium content in flounder liver from various parts of the fjord system. At Norheimsund the cadmium content varied from 0.12 to 2.5 mg/kg with a mean value of 0.40 mg/kg. Already here the cadmium content is four times higher than normal. Liver values of 10.5 mg/kg were found in fish from Eikhamrane and this is the highest value that we have seen in any of the literature. The high cadmium content in flounder liver from the innermost areas of the Sor Fjord clearly showed the effect of cadmium from the jarosite deposits on the bottom. It appears that the cadmium content in flounder liver from the Sor Fjord has increased during the period 1971 to 1984. In general the flounder fillets can be eaten safely; however, flounder liver from the inner areas of the Sor Fjord should not be consumed.

4.6 Lead

4.6.1 Common mussel (Fig. 7)

The lead analysis indicated low values in the outermost areas of the Hardanger Fjord. The values recorded were lower than 1 $mgkg^{-1}$. As with cadmium and zinc, the concentration of lead increased in the common mussel as one moved further into the fjord and at Varaldsoy a concentration of 10 $mgkg^{-1}$ was reached.

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Most noteworthy were the large differences in lead concentrations between natural and bred mussels. Natural mussels from Varaldsoy (south) had values of some 10 $mgkg^{-1}$, while the value for bred mussels was 3 $mgkg^{-1}$. In the inner area of the Hardanger Fjord, the lead pollution was very strong; at Norheimsund (22 cases) one sample had a concentration of 58.3 $mgkg^{-1}$, while another had a concentration of 35 $mgkg^{-1}$. In comparison with data from 1975 (Julshamn, 1981 d), when lead values from the same location of 70 $mgkg^{-1}$, dry weight, or some 10 $mgkg^{-1}$, wet weight, were recorded. This is an increase by a factor of 3 - 5. Great individual variations were also noted. This can be seen in the results from Dale (29 samples). Here the values ranged from 21 $mgkg^{-1}$ to 62 $mgkg^{-1}$. A lead concentration of 175 $mgkg^{-1}$ found in the inner parts of the Sor Fjord is one of the highest reported in the literature. The increase which was found during the period 1975 - 1983 in mussels from Norheimsund can also be seen in the Sor Fjord. The same tendency was reported by NIVA, 1983.

The common mussel lead content is a problem from the nutrition hygiene point of view. The reason is that in Norway a proposal for a maximum limit for fish and shellfish of 3 mg/kg has been proposed. FAO/WHO (1973) has determined an interim acceptable weekly intake for adults of 3.0 mg.

4.6.2 Pollack (Table 4, Fig. 17)

As with cadmium the methods of analysis have been more reliable with regard to the determination of lead in small concentrations. Improved control using blind samples, better temperature control in the furnace and use of matrix modified agents have been effective. The lead content in both pollack fillets and liver was low, with a mean content in the fillet of less than 0.1 mg/kg for the whole fjord system. It was slightly higher for liver. Given the limit values for lead indicated above, the lead content causes no health problems.

4.6.3 Flounder (Table 5, Fig. 18)

All flounder fillets from the whole area had less than 0.1 mg/kg lead content. Nonetheless, the content was slightly higher from locations in the

Sor Fjord. The lead content in flounder fillets remains similar to that reported in 1971 - 1972 by the Environmental Protection Committee in Odda.

The lead content in liver shows an increase of some 40 times when one compares the locations in the outer areas of the Hardanger Fjord with the locations in the Sor Fjord. The mean content was 0.06 mg/kg at Varaldsoy and 3.4 mg/kg at Eikhamrane. The lead content in flounder is not a health problem.

4.7 Mercury

4.7.1 Common mussel (Fig. 18)

The data for mercury are presented in table 1 of the appendix and in figure 7. They show increasing amounts as one moves up the fjord; however, not until Norheimsund and the mouth of the Sor Fjord does the level exceed 0.1 $mgkg^{-1}$. In the Sor Fjord proper the mercury level increased steadily to a maximum concentration at Skjelnes (27 samples) of 1.3 $mgkg^{-1}$. This mercury level is comparable to the samples taken in 1975. The reported results also correspond to those reported by NIVA, 1983.

4.7.2 Pollack (Table 4, Fig. 19)

The mercury content in pollack fillets ranges between 0.071 and 0.22 mg/kg with a mean content of less than 0.12 mg/kg for the whole area, with the exception of samples from Granvin Fjord (Haukaneset) which had a mean content of 0.18 mg/kg. Pollack is a "travelling fish" which will not well reflect the actual mercury content in a given area. The mercury content in pollack is low in comparison with other species. The mercury content in pollack from the Hardanger Fjord is some 2 - 3 times higher than in pollack from the North Sea.

The mercury content in the liver is only half of that in the fillet (Page 32) and no mean content exceeded 0.1 mg/kg.

The health considerations with regard to mercury in foodstuffs are such that the mercury content in pollack is of no consequence to consumption. Several countries have put limits on the amount of mercury in fish. Sweden, at

an early stage, set a maxium limit of 1 mg/kg for fish and shellfish intended for consumption. Authorities generally agree that fish with a mercury content of between 0.2 and 1.0 µg/kg is only safe to eat once per week. Other countries have established a limit of 0.5 mg/kg. FAO/WHO has determined an interim acceptable weekly intake (AWI) of 0.3 mg/person and no more than 0.2 mg may exist of methyl mercury. The health authorities generally consider that fish having a mercury content of less than 0.2 mg/kg can be freely consumed.

4.7.3 Flounder (Table 5, Fig. 20)

The mercury content in the flounder fillets showed a wide range of distribution for all the locations investigated. The results included extreme values of over 1 mg/kg, both in Sor Fjord all the way up to Utne, as well as in the Granvin Fjord (Ulvik). The mean content varied from 0.28 to 0.60 mg/kg. The mercury content in the flounder fillets had dropped somewhat in comparison with the investigations of 1971. The mercury content in liver varied even more than that in fillets. The mean content, some 4 - 5 times higher than in the fillets, was found in liver from the innermost area of the Sor Fjord. However, at lower mercury contents, the fillets and the liver were at the same level of concentration. Extreme values of up to 50.7 mg/kg were found in liver from Krakevikneset. This is the highest value reported for flounder and higher than the most extreme value from 1971. This means that the expected benefit of the stoppage of mercury discharge has yet to become apparent. On the basis of the mean content it could be recommended that flounder fillets from the Sor Fjord could be eaten in the main meal twice a week.

4.8 Farmed fish

The content of copper, zinc, cadmium, lead and mercury in muscle and liver of trout is shown in table 6. It appears that high copper values in the liver is normal for salmon. Investigations at the Nutrition Institute of the

Directorate of Fisheries indicate that the content of copper in the liver can be related to the copper content in the feed and to the age of the fish (Julshamn et al., 1985). The zinc values in muscle and liver fall within the normal range for these species. The cadmium level in the muscle in salmon seems to be only to a limited extent influenced by the generally high level of cadmium in the water. A similar condition exists with regard to lead. The mercury values in the muscle are higher than the corresponding values in the muscle of previously analysed farmed fish. Nonetheless this fish can be consumed without reservation.

This investigation shows that the uptake of the elements copper, zinc, cadmium, lead and mercury is mainly related to the feed and somewhat related to the water.

Table 6: Contents of copper, zinc, cadmium, lead and mercury in the muscle and liver of trout and salmonfrom farming operations in the Hardanger Fjord ($mgkg^{-1}$ fresh weight).

Tabell 6. Innholdet av kobber, sink, kadmium, bly og kvikksølv i muskel og lever av ørret og laks fra oppdrettsanlegg i Hardangerfjorden ($mgkg^{-1}$ frisk vekt).

Species	Location	Organ	Number (n)	Cu	Zn	Cd	Pb	Hg
Trout	Fyksesund	Muscle	4	1.5	2.5	0.005	<0.07	0.05
		Liver	4	81	51	0.015	<0.07	0.11
Salmon	Fyksesund	Muscle	4	1.0	6.1	0.004	<0.07	0.09
		Liver	4	36	27	0.030	<0.07	0.10
Salmon	Strandebarm	Muscle	4	1.2	4.0	0.005	<0.07	0.04
		Liver	4	14	24	0.013	<0.07	0.05

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APPENDIX: TABLES AND FIGURES

Table 1: Heavy metal content in natural and bred common mussels ($mgkg^{-1}$, fresh weight) from the Hardanger Fjord and adjacent fjords.

Tabell 1. Tungmetallinnhold i ville og dyrkede blåskjell ($mgkg^{-1}$ frisk vekt) fra Hardangerfjorden og tilstøtende fjorder.

Location (nr.)	Natural =N Bred =D	Group	Number	Length (mm)	Weight (g)	Dry Substance gkg^{-1}	As $mgkg^{-1}$	Cu $mgkg^{-1}$	Zn $mgkg^{-1}$	Cd $mgkg^{-1}$	Pb $mgkg^{-1}$	Hg $mgkg^{-1}$
1. VALEVÅG	N	1	35	15-20	0.16±0.07	157	1.62	1.23	22.2	1.47	0.88	0.029
	D	1	36	15-20	0.15±0.04	127	1.69	1.33	18.6	0.98	0.67	0.030
	D	2	36	15-20	0.13±0.04	136	1.65	0.95	19.7	1.02	0.68	0.033
2. INDRE TUNGESVIK	N	1	7	40-50	2.16±0.54	147	1.25	0.62	24.1	0.52	1.49	0.016
	N	2	5	40-50	2.73±0.84	164	1.26	1.00	23.6	0.87	1.94	0.030
	N	3	5	40-50	2.84±0.69	154	1.22	0.51	31.2	0.59	1.46	0.023
	D	1	23	20-25	0.33±0.08	112	1.11	1.17	15.7	0.76	0.87	-
	D	2	27	20-25	0.30±0.07	125	1.34	1.21	16.4	0.93	1.10	0.019
	D	3	27	20-25	0.26±0.06	125	1.32	1.21	17.3	0.83	1.23	0.022
	D	4	27	20-25	0.25±0.08	127	1.23	0.77	17.1	0.54	1.12	-
3. ALSAKERNESET	N	1	7	40-50	2.30±0.69	138	1.33	0.58	21.8	0.46	1.91	0.026
	N	2	7	40-50	2.42±0.61	147	1.52	0.75	17.5	0.47	2.75	0.027
	N	3	7	40-45	2.40±0.53	141	1.30	0.34	15.5	0.56	2.02	0.030
	D	1	26	15-20	0.20±0.05	114	0.96	0.58	13.7	0.47	1.98	0.023
	D	2	26	15-20	0.20±0.04	116	1.00	1.02	15.8	0.36	2.66	-
4. SKAALNES	N	1	9	35-40	1.31±0.34	136	1.31	0.70	17.4	0.50	2.70	0.028
	N	2	9	35-40	1.24±0.34	134	1.31	0.68	14.0	0.42	2.07	0.027
	N	3	9	30-40	1.33±0.32	130	1.16	0.31	13.9	0.47	2.68	0.031
	D	1	25	10-20	0.10±0.03	116	1.03	1.35	16.0	0.59	1.69	-
5. TYSSETEIGEN	N	1	15	30-35	0.58±0.12	136	1.11	0.81	11.4	0.53	2.73	0.039
	N	2	16	30-35	0.54±0.15	129	1.24	0.54	11.8	0.65	3.66	0.033
	N	3	18	30-35	0.52±0.17	128	0.95	0.66	13.5	0.72	2.85	0.039

Table 1 cont.

Location (nr.)	Natural=N Bred =D	Group	Number	Length (mm)	Weight (g)	Dry Substance gkg^{-1}	As $mgkg^{-1}$	Cu $mgkg^{-1}$	Zn $mgkg^{-1}$	Cd $mgkg^{-1}$	Pb $mgkg^{-1}$	Hg $mgkg^{-1}$
6. KRINGLENESET	D	1	18	20-25	0.48±0.12	102	1.03	0.71	15.6	0.89	1.50	-
	D	2	23	20-25	0.44±0.19	112	1.08	0.57	17.1	0.95	1.66	0.011
	D	3	23	20-25	0.41±0.07	119	1.34	0.93	19.1	1.24	2.03	0.017
7. LILLE BJELLANDSØY	N	1	6	45-50	4.30±1.08	177	1.46	0.91	30.8	2.07	3.32	-
	N	2	6	45-50	3.98±1.36	184	1.53	1.12	32.6	3.40	6.17	-
	N	3	5	45-50	4.63±1.32	185	1.52	1.11	30.3	2.72	4.35	-
	D	1	15	25-30	0.59±0.15	133	1.42	0.92	30.9	1.34	2.06	-
	D	2	16	25-30	0.57±0.19	152	1.56	1.20	26.7	-	2.40	-
	D	3	18	25-30	0.48±0.10	145	1.63	1.13	24.4	1.79	2.19	-
8. LAUKHAMARSUNDET	N	1	7	40-50	2.68±1.08	188	1.65	1.12	47.7	2.83	5.30	-
	N	2	7	40-50	2.90±1.61	196	1.66	1.18	52.5	4.39	6.17	-
	N	3	7	40-50	2.87±1.78	189	1.79	1.31	47.1	3.68	6.97	-
	D	1	23	20-25	0.40±0.12	113	1.42	0.79	26.2	1.81	1.47	-
	D	2	24	20-25	0.38±0.10	130	1.25	0.78	30.2	2.26	1.76	-
	D	3	24	20-25	0.39±0.13	126	1.39	0.75	30.8	2.06	1.88	-
9. TERØEN	D	1	21	20-25	0.27±0.07	156	1.22	2.19	48.4	5.88	4.66	-
	D	2	21	20-25	0.22±0.08	134	0.79	1.41	47.7	6.06	4.32	-
	D	3	20	20-25	0.22±0.05	130	0.92	2.42	42.9	5.21	3.57	-
10. KALVEN	N	1	5	45-50	3.29±0.42	190	1.90	0.82	63.7	4.87	9.86	-
	N	2	5	45-50	3.74±0.95	182	1.43	0.79	111.0	5.32	7.89	-
	D	1	21	20-30	0.43±0.13	125	1.21	1.32	38.0	5.00	2.89	-
	D	2	19	20-30	0.35±0.07	140	1.41	1.73	37.5	4.13	3.94	-

Table 1 cont.

Location (nr.)	Natural Bred =N =D	Group	Number	Length (mm)	Weight (g)	Dry Substance gkg^{-1}	As $mgkg^{-1}$	Cu $mgkg^{-1}$	Zn $mgkg^{-1}$	Cd $mgkg^{-1}$	Pb $mgkg^{-1}$	Hg $mgkg^{-1}$
11. VARDALSØY SYD	N	1	6	31-45	1.98±1.06	168	1.54	0.72	79.0	4.71	9.09	-
	N	2	6	30-44	2.23±1.14	194	1.46	1.00	83.7	4.71	12.3	-
	D	1	27	15-20	0.19±0.05	113	1.27	1.07	45.9	3.19	2.98	-
	D	2	27	15-20	0.17±0.04	115	1.10	1.00	85.8	3.00	2.25	
12. FUREBERGKNAPPEN	N	1	8	39-43	2.16±0.58	180	1.52	1.23	66.2	3.99	13.2	0.027
	N	2	8	39-43	1.87±0.46	153	1.42	1.06	42.5	3.19	10.2	0.029
	N	3	8	39-45	1.98±0.58	164	1.75	0.84	43.3	3.37	9.56	-
	D	1	18	20-29	0.25±0.07	135	1.29	1.27	39.2	3.10	5.10	0.018
	D	2	23	20-25	0.19±0.05	135	1.35	0.93	40.7	3.06	5.05	0.019
13. LAUVHOBNESET	N	1	5	45-68	5.32±1.29	132	1.62	0.90	59.4	4.49	9.77	0.026
	N	2	5	55-65	6.24±1.61	162	1.76	0.55	56.3	5.14	1.47	0.024
14. AUSTREPOLLEN NORD	N	1	13	30-39	0.78±0.25	118	1.25	0.61	36.3	2.25	5.53	0.020
	N	3	13	31-40	0.77±0.17	125	1.30	0.85	37.9	2.35	6.23	0.039
	D	1	26	20-25	0.17±0.07	109	1.01	0.94	35.9	2.00	4.17	0.016
	D	2	26	20-25	0.15±0.05	107	0.86	0.91	25.0	1.78	4.69	-
15. AUSTREPOLLEN SYD	N	1	18	25-40	0.85±0.28	131	1.31	0.45	31.9	2.28	5.86	0.037
	N	2	19	27-37	0.93±0.34	139	1.48	0.95	52.6	2.75	6.80	0.032
	N	3	18	32-43	1.16±0.27	142	1.51	0.72	37.1	2.66	8.67	-
	N	4	8	40-50	2.12±0.58	142	1.29	0.73	45.2	2.25	9.42	-
16. VARDALSØY NORD	N	1	10	31-36	1.77±0.38	171	1.19	0.88	80.0	5.87	11.4	0.019
	N'	2	10	30-38	1.59±0.65	184	1.45	0.94	108.5	7.41	14.3	0.022
	N	3	10	30-39	1.47±0.82	173	1.43	2.07	89.0	5.47	10.2	-
	D	1	27	15-20	0.26±0.07	116	0.90	0.80	46.9	2.13	3.39	0.019
	D	2	27	15-20	0.23±0.05	114	0.91	0.78	50.5	2.35	3.20	0.021
	D	3	30	15-20	0.20±0.03	114	1.21	0.98	52.0	2.44	5.38	-

Table 1 cont.

Location (nr.)	Natural=N Bred =D	Group	Number	Length (mm)	Weight (g)	Dry Substance gkg^{-1}	As mgkg^{-1}	Cu mgkg^{-1}	Zn mgkg^{-1}	Cd mgkg^{-1}	Pb mgkg^{-1}	Hg mgkg^{-1}
17. STRANDEBARM	N	1	7	34-40	1.75±0.66	138	1.29	0.47	67.0	6.77	8.78	0.021
	N	2	8	36-42	1.62±0.73	138	1.09	0.70	74.0	7.25	13.0	0.015
	N	3	9	33-41	1.30±0.47	124	0.91	0.42	55.5	5.69	13.3	-
	D	1	28	15-20	0.28±0.07	140	1.35	1.18	60.0	3.73	3.63	0.020
	D	2	27	15-20	0.24±0.07	132	1.29	1.35	56.0	3.44	4.45	0.020
	D	3	28	15-20	0.23±0.07	129	1.11	0.89	44.8	2.99	3.40	-
18. DJUPVIKNESET	N	1	17	37-45	2.00±0.57	208	2.14	1.08	78.0	9.01	19.8	0.033
	N	2	17	36-44	2.09±0.68	165	1.36	0.56	61.0	7.03	9.96	0.038
	N	3	12	37-43	1.51±0.53	171	1.17	0.87	69.0	8.05	10.7	0.034
	N	4	12	34-43	1.47±0.40	168	1.35	1.16	68.0	7.93	10.8	-
19. STRAUMESTEINEN	N	1	14	28-40	1.10±0.38	210	1.66	1.43	116.5	11.3	18.9	-
	N	2	15	30-40	0.95±0.28	168	1.23	0.57	66.5	7.38	12.0	-
	N	3	10	40-47	1.68±0.33	170	1.72	1.14	95.0	7.95	24.6	0.055
	N	5	5	47-55	2.63±0.25	171	1.65	0.88	83.0	7.53	20.4	0.047
20. DYSVIKNESET	N	1	24	30-35	0.83±0.19	187	1.61	1.28	81.0	1.28	13.9	0.041
	N	3	7	37-42	1.21±0.42	149	1.29	0.77	68.5	0.77	18.5	0.078
	N	4	10	35-45	0.92±0.24	202	1.45	1.38	133.0	1.38	26.7	0.080
	N	5	8	35-44	0.94±0.26	177	1.64	1.20	111.0	1.20	17.1	-
	N	6	4	48-55	2.60±0.89	147	1.41	1.52	65.0	1.52	76.0	-
21. RYKKJENESET	N	1	14	32-40	0.94±0.31	163	1.21	1.40	77.4	8.85	40.7	-
	N	2	15	34-40	1.28±0.33	163	1.35	1.09	67.1	9.11	47.4	0.078
	N	3	15	32-40	1.16±0.28	187	1.70	1.60	78.8	9.67	57.7	-
	N	4	15	33-46	1.22±0.31	170	1.58	0.87	122.0	10.1	-	0.380
	N	5	8	46-62	1.85±0.64	158	2.15	0.81	146.0	9.47	-	0.139

Table 1 cont.

Location (nr.)	Natural=N Bred =D	Group	Number	Length (mm)	Weight (g)	Dry Substance gkg^{-1}	As $mgkg^{-1}$	Cu $mgkg^{-1}$	Zn $mgkg^{-1}$	Cd $mgkg^{-1}$	Pb $mgkg^{-1}$	Hg $mgkg^{-1}$
22. FRAMNES	N	1	13	32-41	0.81±0.23	143	1.20	0.99	78.7	6.87	36.9	0.057
	N	2	11	33-42	0.94±0.43	153	1.11	1.32	90.1	7.81	35.2	0.057
	N	3	12	32-40	0.84±0.26	144	1.22	1.23	90.6	9.39	58.3	0.075
	D	1	19	15-20	0.15±0.03	153	1.46	1.05	59.9	3.91	20.5	0.049
	D	2	19	15-20	0.15±0.05	145	1.28	0.99	58.2	3.35	18.9	0.058
23. VINEGNESET	N	1	11	35-43	1.29±0.55	167	1.47	1.73	139.0	13.9	76.9	0.043
	N	2	12	33-42	1.13±0.39	177	1.39	0.90	101.0	12.7	55.4	0.068
	N	3	11	35-43	1.17±0.42	175	1.30	1.20	97.3	11.5	-	0.053
24. HAUSTVEIT	N	1	10	45-55	4.45±0.93	157	1.48	1.34	163.0	10.3	174	0.167
	N	2	10	45-60	4.17±1.89	163	1.50	1.11	178.0	11.0	199	0.119
	N	3	9	34-40	1.68±0.44	166	1.56	1.41	121.0	11.5	118	0.101
25. KRAAKEVIKNESET	N	1	18	25-33	0.45±0.12	123	1.18	0.85	125.0	19.4	133	0.175
	N	2	19	22-30	0.43±0.13	116	1.19	1.18	118.0	18.9	108	0.149
26. NORDNES	N	1	14	37-43	1.52±0.52	143	1.69	0.99	100.0	17.6	175	0.248
	N	2	11	37-44	1.35±0.48	134	1.43	1.15	131.0	18.3	131	0.402
	N	3	11	36-43	1.19±0.49	157	1.61	1.05	115.0	17.5	141	0.464
27. SKJELNES	N	1	21	28-38	0.90±0.22	158	1.80	1.91	151.0	20.4	163	1.09
	N	2	24	28-36	0.97±0.28	156	1.57	1.59	144.0	20.0	134	1.32
28. BØRVE	N	1	24	20-29	0.45±0.19	137	1.59	2.31	88.3	24.2	31.6	0.55
	N	2	23	21-31	0.42±0.12	138	1.58	1.27	92.8	26.8	34.6	0.56
	N	3	23	20-27	0.36±0.10	129	1.22	1.00	95.2	22.7	29.3	0.41
29. DALE	N	1	11	34-43	1.48±0.49	164	1.56	1.00	156.0	20.0	61.6	0.171
	N	2	11	35-40	1.43±0.28	173	1.76	1.36	84.3	16.6	21.4	0.175
	N	3	10	35-42	1.63±0.68	170	1.56	0.73	80.4	16.2	29.1	0.173

Table 1 cont.

Location (nr.)	Natural=N Bred =D	Group	Number	Length (mm)	Weight (g)	Dry Substance gkg^{-1}	As $mgkg^{-1}$	Cu $mgkg^{-1}$	Zn $mgkg^{-1}$	Cd $mgkg^{-1}$	Pb $mgkg^{-1}$	Hg $mgkg^{-1}$
30. ULSNES	N	1	11	35-43	1.23±0.42	144	0.95	0.86	82.7	13.0	35.1	0.107
	N	2	11	33-43	1.00±0.32	137	1.17	1.03	105.0	16.9	44.6	0.106
	N	3	11	35-44	1.18±0.63	138	1.20	0.57	97.9	15.0	56.5	0.113
31. FUREBERGNESET	N	1	26	10-20	0.17±0.05	159	1.47	0.97	49.6	6.27	4.97	0.055
	N	2	30	10-20	0.12±0.03	160	1.46	0.97	52.5	6.39	-	0.042
32. DJUPEVIK	N	1	15	10-20	0.14±0.09	191	1.61	1.49	44.1	6.45	2.93	0.049
33. VIKANE	N	1	15	23-30	0.49±0.16	139	1.16	0.60	74.1	8.98	28.3	0.059
	N	2	15	23-29	0.49±0.17	134	1.08	0.80	86.9	8.42	30.6	0.069
	N	3	18	23-29	0.39±0.12	136	1.15	0.57	91.7	8.64	20.9	0.076
34. STARTANESET	N	1	13	29-35	0.77±0.25	139	1.06	0.34	43.5	11.7	10.9	0.070
	N	2	13	28-35	0.76±0.23	129	1.06	0.53	42.1	10.0	15.5	0.065
	N	3	12	29-38	0.82±0.37	134	1.07	0.58	44.5	13.3	12.6	0.074
35. STAVANESET	N	1	11	21-33	0.56±0.23	146	0.97	0.62	43.7	9.69	15.8	-
	N	2	11	23-36	0.55±0.21	136	1.21	0.58	48.8	8.85	19.1	-
	N	3	11	24-35	0.58±0.24	133	1.03	0.77	65.8	9.71	23.7	-
36. TEISTEBERGET	N	1	18	30-41	0.74±0.24	160	1.44	0.99	115.0	13.4	40.3	0.201
	N	2	27	26-32	0.38±0.09	163	1.59	1.28	125.0	15.8	37.6	0.112
	N	3	24	26-35	0.44±0.17	181	1.76	1.09	128.0	15.9	38.8	0.180

Table 2: Trace elements in pollack from the Hardanger Fjord and adjacent fjords. (The values are based on fresh weight; F = fillet and L = liver; ♂ = male and ♀ = female; i.b. = not determined).

Tabell 2. Sporelementinnhold i sei fra Hardangerfjorden og tilstøtende fjorder. (Verdiene er basert på frisk vekt; F=filet og L=lever; ♂=hankjønn og ♀=hunkjønn; i.b.=ikke bestemt.)

Sex	Age (year)	Length (cm)	Dry Substance Weight gkg^{-1}	As mgkg^{-1}		Cu mgkg^{-1}		Zn mgkg^{-1}		Cd µgkg^{-1}		Pb µgkg^{-1}		Hg mgkg^{-1}	
				F	L	F	L	F	L	F	L	F	L	F	L
Varaldsøy															
♀		48	1.2	211	3.0	6.7	0.81	4.5	4.3	14.7	4.7	89	0.02	<0.05	0.11	0.02
♀		50	1.2	227	3.0	6.2	0.87	5.3	4.4	18.6	9.5	99	0.08	<0.05	0.11	0.04
♀		52	1.2	231	3.4	5.0	0.89	5.4	4.7	14.3	i.b.	130	0.03	<0.05	0.11	0.03
♂		50	1.3	224	2.8	4.5	0.86	7.6	4.4	16.4	4.8	110	0.08	<0.05	0.11	0.07
♀		50	1.3	225	2.1	3.3	0.86	5.6	4.6	17.5	5.9	100	0.05	0.20	0.11	0.05
♀		51	1.3	224	2.3	4.9	0.87	6.3	4.3	21.5	4.0	88	0.01	<0.05	0.11	0.04
♂		51	1.3	219	2.8	4.4	0.84	7.8	4.2	18.2	4.1	130	0.03	<0.05	0.09	0.04
♂		52	1.4	227	3.4	6.2	0.88	7.6	3.9	20.7	5.7	150	0.12	0.05	0.09	0.03
♂		52	1.4	220	3.0	4.3	0.84	4.2	4.0	11.6	8.9	56	0.14	0.06	0.11	0.03
♀		52	1.5	225	2.6	4.9	0.86	7.1	4.5	16.3	5.5	99	0.01	<0.05	0.11	0.04
Strandebarm																
♀		43	0.9	234	1.8	5.2	0.66	3.3	4.9	19.4	4.2	129	0.04	<0.05	0.08	0.05
♀		45	1.0	223	1.5	4.6	0.70	3.4	4.1	17.7	3.0	92	0.02	<0.05	0.09	0.03
♀		48	1.1	227	1.6	4.0	0.62	5.9	5.1	16.5	3.4	91	0.04	<0.05	0.08	0.06
♂		48	1.1	229	1.2	3.6	0.68	6.0	5.1	17.6	3.3	136	0.02	0.05	0.09	0.07
♀		52	1.4	228	2.3	4.2	0.60	4.6	4.4	12.8	6.6	75	0.19	0.09	0.10	0.03
♀		52	1.5	226	1.1	3.6	0.57	3.0	4.3	21.8	2.8	41	0.03	<0.05	0.10	0.07
♀		53	1.6	231	1.7	3.8	0.62	5.2	4.4	15.5	3.0	76	0.05	0.15	0.09	0.06
♂		56	1.7	235	1.2	3.1	0.65	1.8	4.8	13.5	4.1	58	0.05	<0.05	0.09	0.06
♀		55	1.8	226	1.4	3.0	0.71	4.7	3.7	14.9	5.4	41	0.02	<0.05	0.07	0.06
♂		57	1.9	223	i.b.	i.b.	i.b.	4.0	i.b.	11.5	i.b.	62	i.b.	0.05	0.09	0.05
♀		53	1.9	236	2.0	3.7	0.66	4.2	4.7	21.1	5.2	32	0.08	<0.05	0.07	0.06
Norheimsund																
♀		47	1.4	222	1.1	5.2	0.86	2.0	3.1	11.5	2.9	75	0.04	<0.05	0.10	0.06
♂		53	1.6	227	1.7	2.9	0.89	2.9	4.0	11.6	4.6	33	0.07	<0.05	0.10	0.05
♀		53	1.6	220	2.1	3.7	0.85	3.9	4.4	12.3	4.8	78	0.07	<0.05	0.11	0.05
♂		55	1.9	225	1.7	i.b.	0.87	2.5	5.1	8.3	4.1	i.b.	0.07	<0.05	0.12	0.04
♀		55	2.0	226	2.0	4.7	0.88	2.3	4.9	9.2	4.9	55	0.06	<0.05	0.10	0.07
♀		55	2.0	223	1.2	3.8	0.87	3.3	4.5	12.9	3.8	49	0.03	<0.05	0.09	0.06
♀		55	2.0	220	1.5	7.3	0.85	3.5	4.1	9.6	4.6	49	0.05	0.05	0.11	0.06
♂		58	2.2	225	1.8	5.1	0.85	2.4	4.8	10.1	5.4	61	0.08	0.07	0.10	0.06
i.b.		68	2.7	225	1.4	2.6	0.87	3.5	4.6	13.1	4.9	86	0.07	<0.05	0.11	0.06
♂		65	3.0	225	1.4	3.6	0.86	2.9	3.7	8.6	3.8	40	0.05	<0.05	0.14	0.06

Table 2: Trace elements in pollack from the Hardanger Fjord and adjacent fjords (cont.).

Tabell 2. Sporelementinnhold i sei fra Hardangerfjorden og tilstøtende fjorder. (forts.).

Sex	Age (year)	Length cm	Weight (kg)	Dry Substance gkg^{-1}	As $mgkg^{-1}$		Cu $mgkg^{-1}$		Zn $mgkg^{-1}$		Cd μgkg^{-1}		Pb $mgkg^{-1}$		Hg $mgkg^{-1}$	
				F	F	L	F	L	F	L	F	L	F	L	F	L
Herand																
♂		48	1.1	230	2.2	9.1	0.88	4.5	5.5	17.6	5.2	90	0.02	<0.05	0.08	0.03
♂		50	1.4	239	2.9	3.1	0.92	3.6	5.8	16.7	4.9	100	0.08	<0.05	0.10	0.06
♂		51	1.4	228	2.2	4.6	0.87	3.7	4.8	18.7	5.6	110	0.01	<0.05	0.08	0.07
♀		51	1.4	234	3.1	4.8	0.91	5.2	5.5	19.2	4.7	127	0.02	<0.05	0.11	0.06
♂		53	1.4	225	2.5	9.6	0.87	2.7	4.2	22.0	4.3	100	0.02	0.08	0.08	0.04
♂		51	1.6	228	2.0	6.8	0.88	5.4	4.3	17.2	4.1	85	0.02	<0.05	0.11	0.05
♀		53	1.6	229	2.5	10.0	0.88	3.5	5.6	14.0	4.0	138	0.02	0.05	0.08	0.04
♀		54	1.6	230	2.2	4.6	0.89	1.7	4.9	16.3	5.0	71	0.05	0.05	0.10	0.06
♀		55	1.8	222	2.0	4.3	0.84	5.2	4.8	20.4	9.1	120	0.01	<0.05	0.10	0.07
♀		60	2.3	225	1.5	14.7	0.86	5.6	3.8	16.4	1.6	70	0.06	<0.05	0.13	0.04
Haukaneset																
♂		63	1.5	210	i.b.	25.0	i.b.	5.6	i.b.	13.6	i.b.	120	i.b.	0.13	0.11	0.07
♂		65	2.1	198	2.3	3.3	0.72	1.8	3.6	13.4	4.8	150	<0.01	0.10	0.15	0.10
♀		61	2.2	200	i.b.	47.9	i.b.	11.0	i.b.	29.9	i.b.	370	i.b.	0.18	0.11	0.10
♂		69	2.3	199	3.7	4.0	0.74	8.8	4.5	21.0	5.0	340	0.04	0.11	0.11	0.05
♂		62	2.5	197	i.b.	6.5	i.b.	6.9	i.b.	15.0	i.b.	80	i.b.	0.16	0.08	0.05
♂		81	2.5	197	5.4	9.4	0.76	9.9	3.6	42.4	1.2	i.b.	0.03	0.05	0.17	0.10
♂		60	2.6	199	2.6	6.4	0.76	12.2	4.2	23.2	7.8	130	0.20	0.16	0.19	0.09
♀		68	2.6	190	1.5	4.5	0.62	7.3	3.2	12.3	1.8	130	0.01	0.10	0.21	0.09
♀		73	2.8	199	3.0	10.0	1.0	8.5	3.5	14.4	4.6	200	0.02	0.16	0.12	0.06
♀		80	3.4	202	6.8	15.3	0.69	16.4	3.9	33.7	9.2	300	0.02	0.18	0.19	0.17
♂		78	3.5	199	1.6	8.4	1.0	7.6	3.7	13.3	6.1	150	<0.01	0.13	i.b.	0.09
♀		72	3.7	205	5.3	11.2	0.79	7.3	3.7	20.3	1.5	170	0.02	0.18	0.22	0.09
♀		80	3.7	195	2.6	16.7	0.71	8.3	3.4	27.7	3.0	220	<0.01	0.12	0.13	0.14

Table 2: Trace elements in pollack from the Hardanger Fjord and adjacent fjords (cont.).

Tabell 2. Sporelementinnhold i sei fra Hardangerfjorden. (forts.)

Sex	Age (year)	Length (cm)	Weight (kg)	Dry Substance gkg^{-1}	As $mgkg^{-1}$		Cu $mgkg^{-1}$		Zn $mgkg^{-1}$		Cd μgkg^{-1}		Pb $mgkg^{-1}$		Hg $mgkg^{-1}$	
				F	F	L	F	L	F	L	F	L	F	L	F	L
Grimo																
♂		53	1.2	211	10.1	25.4	0.74	3.6	5.4	19.3	4.6	350	0.01	0.06	0.18	0.11
♂		53	1.3	212	8.6	18.6	1.1	9.2	5.1	33.0	1.7	330	0.01	0.28	0.10	0.08
♂		54	1.3	204	6.9	14.9	0.99	4.6	5.0	35.2	3.5	580	0.05	0.05	0.08	i.b.
♀		53	1.4	213	8.6	25.3	0.71	5.0	4.2	23.8	4.2	160	0.03	0.17	0.11	0.08
♂		53	1.5	216	12.6	35.0	0.82	2.9	4.9	18.8	1.1	130	<0.01	0.05	0.13	0.07
♀		55	1.6	213	12.6	25.8	0.78	3.1	4.1	14.1	4.7	110	0.01	0.14	0.15	i.b.
♀		55	1.7	212	13.5	21.8	0.81	2.7	3.9	24.0	7.4	130	0.05	0.02	0.08	0.07
♀		58	1.7	214	8.2	21.0	0.66	4.2	4.6	17.9	9.4	170	0.02	0.12	0.12	0.05
♀		52	1.8	217	11.7	21.1	0.77	5.2	4.2	20.3	5.4	140	0.01	0.18	0.17	0.04
♀		58	1.9	217	12.0	44.0	0.79	4.2	4.5	21.6	8.1	120	<0.01	0.05	0.11	0.05
♀		57	2.0	222	10.8	15.7	0.81	4.4	4.4	23.4	7.5	260	0.01	0.07	0.15	0.05
♂		65	2.0	212	8.8	59.7	0.75	7.0	4.3	28.1	5.3	440	0.01	0.05	0.09	0.07
♂		64	2.1	213	4.6	5.9	0.74	2.1	4.1	14.1	1.9	130	0.02	0.09	0.16	0.09
♂		59	2.2	221	12.3	25.0	0.82	3.9	4.1	22.6	4.2	110	0.01	0.09	0.11	0.05
♂		65	2.2	209	9.3	12.3	0.77	2.8	3.3	17.4	4.5	163	0.01	0.05	0.11	0.05
♂		62	2.3	218	11.2	28.9	0.71	6.6	3.8	27.2	1.0	33	0.02	0.05	0.08	0.08
♀		63	2.4	215	10.2	13.8	0.79	5.5	4.1	22.5	1.1	150	0.02	0.05	0.10	i.b.
♂		65	2.6	211	8.2	12.7	0.76	8.9	4.7	22.8	2.2	170	0.01	0.05	0.10	0.08
♀		70	2.8	211	5.6	9.2	0.73	6.1	3.4	18.9	0.8	100	0.01	0.05	0.10	0.06

Table 2: Trace elements in pollack from the Hardanger Fjord and adjacent fjords (cont.).

Tabell 2. Sporelementinnhold i sei fra Hardangerfjorden. (forts.)

Sex	Age (year)	Length (cm)	Weight (kg)	Dry Substance gkg^{-1}	As $mgkg^{-1}$		Cu $mgkg^{-1}$		Zn $mgkg^{-1}$		Cd μgkg^{-1}		Pb $mgkg^{-1}$		Hg $mgkg^{-1}$	
				F	F	L	F	L	F	L	F	L	F	L	F	L
Utne																
♂		53	1.3	223	6.3	11.2	0.80	7.0	4.4	22.9	2.5	150	0.04	0.05	0.09	0.02
♂		53	1.4	217	6.4	6.9	0.70	4.1	3.7	14.1	i.b.	59	0.02	<0.05	0.08	0.02
♂		54	1.4	230	6.1	7.7	0.80	4.9	4.2	13.5	3.8	80	0.04	<0.05	0.09	0.03
♂		55	1.4	224	5.5	7.3	0.78	3.4	4.4	13.3	1.6	130	0.01	0.50	0.08	0.02
♀		55	1.5	220	4.9	6.6	0.71	4.4	3.9	16.5	2.5	86	0.04	0.25	i.b.	0.05
♂		54	1.6	218	5.6	5.7	0.85	4.2	4.1	16.6	1.5	75	0.11	0.10	0.11	0.02
♀		55	1.6	229	4.7	7.6	0.76	5.9	4.0	15.9	8.0	79	0.02	0.29	0.14	0.05
♂		55	1.7	217	5.4	6.2	0.75	3.7	3.7	16.5	3.9	100	0.03	0.07	0.09	0.04
♀		55	1.8	229	3.6	7.4	0.72	7.5	4.4	19.3	1.7	96	0.01	0.06	0.11	0.04
♀		60	2.0	240	5.3	8.4	0.92	5.4	5.3	14.5	1.5	78	0.02	<0.05	0.10	0.05
♀		60	2.0	232	4.2	7.7	0.85	4.3	4.6	13.0	9.2	84	0.02	0.05	0.10	0.02
♀		60	2.0	226	4.4	7.9	0.73	5.7	4.1	13.3	1.4	95	0.02	0.05	0.11	0.02
♀		60	2.1	225	5.5	9.8	0.87	5.2	3.5	14.4	7.4	76	0.03	<0.05	0.09	0.05
♀		60	2.1	221	3.7	7.8	1.1	10.9	3.6	19.0	3.3	140	0.02	0.07	0.12	0.05
♀		60	2.2	226	4.0	7.9	0.77	3.7	3.9	18.2	3.0	96	0.03	<0.05	0.10	0.05
♂		60	2.2	218	4.3	8.2	0.80	9.0	3.7	18.5	1.6	120	0.02	0.08	0.12	0.05
♀		62	2.3	221	4.4	9.4	0.80	5.3	4.0	15.8	3.2	91	0.01	<0.05	0.10	0.02
♀		64	2.4	223	3.7	5.9	0.81	6.5	3.8	16.4	2.9	71	0.06	<0.05	0.13	0.05
♂		65	2.4	212	4.0	16.0	0.78	9.6	3.4	22.4	6.0	123	0.01	<0.05	0.10	0.05
♀		65	2.8	215	i.b.	8.4	i.b.	5.6	i.b.	14.2	i.b.	59	i.b.	<0.05	0.14	0.05

Table 2: Trace elements in pollack from the Hardanger Fjord and adjacent fjords (cont.).

Tabell 2. Sporelementinnhold i sei fra Hardangerfjorden. (forts.)

Sex	Age (year)	Length (cm)	Weight (kg)	Dry Substance gkg^{-1}	As $mgkg^{-1}$		Cu $mgkg^{-1}$		Zn $mgkg^{-1}$		Cd μgkg^{-1}		Pb $mgkg^{-1}$		Hg $mgkg^{-1}$	
				F	F	L	F	L	F	L	F	L	F	L	F	L
Eikhamrane																
♀		43	0.8	217	4.9	6.0	0.80	3.5	4.3	14.3	2.2	250	0.03	0.07	0.13	0.08
♀		51	1.1	206	9.8	22.1	0.76	4.6	5.0	17.7	4.7	320	0.01	0.05	0.14	0.14
♀		53	1.3	208	7.7	16.7	0.69	4.7	4.6	23.5	4.5	300	0.01	0.05	0.12	0.09
♂		55	1.7	213	9.9	29.6	1.2	3.7	4.8	36.4	3.4	166	0.04	0.06	0.07	0.05
♀		53	1.6	208	10.4	45.2	0.77	6.3	5.4	25.0	4.2	330	0.01	0.08	0.13	0.07
♀		60	1.7	215	6.6	16.6	0.80	5.0	4.9	27.0	1.0	280	0.02	0.18	0.11	0.08
♀		55	1.8	210	11.3	30.8	0.71	7.1	4.2	34.4	3.0	150	0.01	0.05	0.15	0.08
♀		55	1.8	214	13.3	36.6	0.79	2.5	4.8	17.3	4.2	170	<0.01	<0.05	0.12	0.06
♂		57	1.8	210	10.6	36.6	0.70	3.4	4.8	20.3	1.3	230	<0.01	<0.05	0.10	0.03
♀		58	1.8	221	10.4	20.2	0.69	3.4	4.3	11.4	2.9	65	0.02	0.05	0.14	0.05
♀		59	1.9	204	8.2	19.3	0.76	6.9	4.7	26.2	5.2	140	0.01	<0.05	0.08	0.05
♀		59	1.9	211	9.9	32.3	0.77	3.8	4.8	32.7	2.8	190	0.06	<0.05	0.09	0.08

Table 3: Trace elements in flounder from the Hardanger Fjord and adjacent fjords. (The values are based on fresh weight; F = fillet and L = liver; ♂ = male and ♀ = female).

Tabell 3. Sporelementinnhold i flyndre fra Hardangerfjorden og tilstøtende fjorder. (Verdiene er basert på frisk vekt; F=filet og L=lever; ♂=hankjønn og ♀=hunkjønn).

Sex	Age (year)	Length (cm)	Weight (g)	Dry Substance gkg^{-1} F	Dry Substance gkg^{-1} L	As mgkg^{-1} F	As mgkg^{-1} L	Cu mgkg^{-1} F	Cu mgkg^{-1} L	Zn mgkg^{-1} F	Zn mgkg^{-1} L	Cd µgkg^{-1} F	Cd µgkg^{-1} L	Pb mgkg^{-1} F	Pb mgkg^{-1} L	Hg mgkg^{-1} F	Hg mgkg^{-1} L
Varaldsøy																	
♀		32	250	228	458	26.9	15.3	0.20	0.91	3.5	10.5	<0.5	140	0.10	0.47	0.19	0.11
♂		35	300	219	420	10.8		0.84		4.2	i.b.	"	i.b.	<0.02	i.b.	i.b.	i.b.
♂		30	350	244	397	11.2	11.6	0.80	0.79	3.6	22.5	"	180	0.02	0.12	0.22	0.31
♀		40	400	215	382	31.8	24.6	0.20	0.69	3.4	21.0	"	150	0.02	0.20	0.55	0.28
♀		40	500	220	420	11.5	8.4	0.86	4.2	3.6	59.2	"	290	<0.02	0.09	i.b.	0.29
♂		42	500	229	494	12.5	11.9	0.36	10.2	3.8	47.6	"	380	<0.02	0.11	0.21	0.29
Strandebarm																	
♂		30	200	201	461	7.2	5.2	0.25	11.1	3.9	47.8	<0.5	190	<0.02	0.06	0.30	0.50
♂	5	30	250	218	i.b.	i.b.	i.b.	i.b.	i.b.	i.b.	i.b.	i.b.	i.b.	i.b.	i.b.	0.14	i.b.
♀	2	35	350	214	399	4.3	7.8	0.18	6.7	3.5	58.9	<0.5	63	<0.02	0.04	0.08	0.15
♂	i.b.	35	400	212	394	25.2	32.8	0.20	7.1	3.1	77.2	"	80	"	0.14	0.25	0.28
♀	4	38	425	228	557	7.4	5.5	<0.10	9.9	3.5	76.5	"	52	0.03	0.09	0.13	0.08
♂	6	40	500	231	555	8.0	10.6	"	4.0	3.6	73.9	"	56	0.02	0.05	0.11	0.09
♀	7	40	550	224	519	10.6	6.6	"	13.6	3.1	69.5	"	92	<0.02	0.09	0.36	0.24
♀	i.b.	40	600	214	391	9.6	10.0	"	3.1	3.1	72.7	"	86	"	0.08	0.14	0.09
♂	8	45	600	224	471	11.3	10.3	"	3.5	4.4	95.5	"	76	0.02	0.10	0.53	0.39
♂	9	45	650	201	273	11.5	15.8	"	5.2	2.4	46.7	"	237	<0.02	0.28	0.66	0.91
♀	7	45	700	219	i.b.	7.3	i.b.	"	i.b.	3.3	i.b.	"	i.b.	"	i.b.	0.39	i.b.

Table 3: Trace elements in flounder from the Hardanger Fjord and adjacent fjords (cont.).

Tabell 3. Sporelementinnhold i flyndre fra Hardangerfjorden og tilstøtende fjorder. (forts.)

Sex	Age (year)	Length (cm)	Weight (g)	Dry Substance gkg^{-1} F	Dry Substance gkg^{-1} L	As mgkg^{-1} F	As mgkg^{-1} L	Cu mgkg^{-1} F	Cu mgkg^{-1} L	Zn mgkg^{-1} F	Zn mgkg^{-1} L	Cd µgkg^{-1} F	Cd µgkg^{-1} L	Pb mgkg^{-1} F	Pb mgkg^{-1} L	Hg mgkg^{-1} F	Hg mgkg^{-1} L
Norheimsund																	
♂	i.b.	30	250	207	379	9.6	13.8	0.18	15.3	3.4	77.0	1.8	115	<0.02	0.17	0.06	0.50
♂	5	30	250	217	532	i.b.	i.b.	i.b.	i.b.	i.b.	i.b.	i.b.	i.b.	i.b.	i.b.	0.09	0.13
♂	3	33	300	208	459	9.5	7.7	0.15	6.6	3.6	64.6	i.b.	140	0.04	0.08	0.29	0.41
♀	6	35	300	203	373	i.b.	i.b.	i.b.	i.b.	i.b.	i.b.	i.b.	i.b.	i.b.	i.b.	0.09	0.31
♀	i.b.	36	300	183	270	61.7	35.0	0.12	1.3	3.4	30.7	16.8	2460	0.21	7.5	0.83	1.0
♂	7	36	350	194	787	10.1	34.1	0.15	39.0	3.2	136	1.3	716	0.03	0.20	0.71	3.8
♂	6	35	370	201	377	11.4	6.4	<0.10	18.2	4.1	68.8	<0.5	157	<0.02	0.11	0.56	0.61
♀	7	40	450	222	509	5.2	4.3	"	3.6	3.4	84.1	2.0	166	0.03	0.12	0.11	0.13
i.b.	7	40	450	171	242	i.b.	i.b.	i.b.	i.b.	i.b.	i.b.	i.b.	i.b.	i.b.	i.b.	0.62	5.1
♀	i.b.	37	500	205	568	5.8	5.2	0.15	13.6	3.9	90.9	8.7	181	0.03	0.10	0.19	0.24
♂	8	40	500	233	799	i.b.	i.b.	i.b.	i.b.	i.b.	i.b.	i.b.	i.b.	i.b.	i.b.	0.25	i.b.
♂	8	40	500	214	447	28.1	12.5	0.16	15.7	3.1	49.3	6.8	207	<0.02	0.05	0.46	0.56
♂	7	40	550	216	476	11.2	12.2	<0.12	8.1	3.8	71.4	1.0	187	0.02	0.10	0.16	0.45
♀	i.b.	45	750	210	467	i.b.	i.b.	i.b.	i.b.	i.b.	i.b.	i.b.	i.b.	i.b.	i.b.	0.58	0.94
♀	i.b.	45	800	222	559	i.b.	i.b.	i.b.	i.b.	i.b.	i.b.	i.b.	i.b.	i.b.	i.b.	0.25	i.b.
♀	9	50	1150	209	605	15.4	13.5	0.15	13.4	2.9	99.5	1.3	311	0.05	0.05	0.60	0.85
Herand																	
♀	3	28	300	207	386	5.8	2.0	0.69	6.6	5.3	38.1	1.4	790	0.02	1.3	0.07	0.07
♂	4	34	300	213	356	7.5	4.2	0.20	6.1	3.1	56.7	3.2	143	0.07	0.06	0.29	0.33
♂	3	35	400	208	i.b.	i.b.	i.b.	i.b.	i.b.	i.b.	i.b.	i.b.	i.b.	i.b.	i.b.	0.28	i.b.
♀	4	35	450	295	406	24.7	13.1	0.15	29.3	4.8	78.3	1.4	164	0.02	0.08	0.55	0.52
♀	5	36	450	214	560	9.0	13.3	<0.10	19.5	3.2	61.5	1.5	123	0.05	0.02	0.14	0.15
♂	6	40	500	208	331	11.6	5.4	0.15	12.8	3.9	66.4	0.85	165	0.05	0.09	0.34	0.20
♂	5	40	550	216	459	5.7	0.62	0.12	1.0	4.2	30.1	0.5	374	0.05	0.11	0.09	0.06
♂	6	40	600	210	498	15.6	10.2	0.26	16.4	3.9	70.0	<0.5	97	0.01	0.05	0.46	0.28
♀	7	45	600	195	277	8.9	12.3	0.62	5.1	4.6	50.8	0.5	363	0.02	0.16	0.77	0.52
♂	7-8	42	600	193	386	i.b.	i.b.	i.b.	i.b.	i.b.	i.b.	i.b.	i.b.	i.b.	i.b.	0.60	0.72
♀	9	50	1100	219	515	5.5	i.b.	0.24	4.1	3.1	99.1	0.5	81	0.01	0.02	0.47	0.25

Table 3: Trace elements in flounder from the Hardanger Fjord and adjacent fjords (cont.).

Tabell 3. Sporelementinnhold i flyndre fra Hardangerfjorden og tilstøtende fjorder. (forts.)

Sex	Age (year)	Length (cm)	Weight (g)	Dry Substance gkg^{-1} F	Dry Substance gkg^{-1} L	As mgkg^{-1} F	As mgkg^{-1} L	Cu mgkg^{-1} F	Cu mgkg^{-1} L	Zn mgkg^{-1} F	Zn mgkg^{-1} L	Cd µgkg^{-1} F	Cd µgkg^{-1} L	Pb mgkg^{-1} F	Pb mgkg^{-1} L	Hg mgkg^{-1} F	Hg mgkg^{-1} L
Haukaneset																	
i.b.	3	23	81	189	250	49.2	38.3	0.24	2.7	4.5	52.2	5.8	2300	0.14	1.2	0.98	1.04
♂	5	30	173	216	265	41.3	20.0	0.25	9.2	3.4	47.1	1.2	463	0.03	0.40	1.3	i.b.
♂	4	30	217	201	351	14.0	12.1	0.21	3.3	2.7	59.1	0.5	446	0.02	0.20	0.61	1.2
♂	4	26	222	208	267	5.4	6.6	0.24	16.7	5.5	53.5	24.9	3240	0.12	0.52	0.08	0.10
♂	4	34	299	211	254	3.3	9.8	0.27	31.5	7.1	62.8	10.0	496	0.02	0.48	0.22	0.98
♀	5	37	344	196	324	14.4	10.8	0.21	23.4	6.9	76.5	0.5	532	0.02	0.20	0.38	0.49
♀	5	40	451	202	249	69.6	41.5	0.23	19.5	3.1	64.7	0.5	282	0.02	0.32	i.b.	1.2
Ulvik																	
♂	i.b.	20	180	190	242	31.7	22.5	0.66	22.5	3.3	54.8	3.9	531	0.02	2.5	0.77	i.b.
♂	3	27	200	195	243	4.0	5.8	0.24	6.2	6.0	39.3	1.3	534	0.02	0.41	0.13	i.b.
i.b.	2-3	28	150	164	410	30.2	13.7	0.21	2.1	3.2	25.8	1.0	296	0.07	2.2	0.17	i.b.
Utne																	
♂	4-5	33	200	182	222	9.3	16.5	0.20	4.9	3.6	45.3	0.5	314	0.02	0.17	0.50	i.b.
♂	6	36	400	205	393	5.6	4.8	0.30	17.2	4.7	84.6	1.3	164	0.04	0.18	0.33	0.51
♂	7	40	450	189	i.b.	1.4	i.b.	0.70	i.b.	4.5	i.b.	1.7	i.b.	0.02	i.b.	0.64	i.b.
♀	8	45	650	203	347	4.9	4.2	0.22	14.2	4.3	67.7	0.5	204	0.02	0.09	0.33	0.87
♂	5	40	700	212	313	6.9	11.2	0.73	24.8	4.1	47.8	1.5	545	0.03	0.14	0.25	0.16
♀	6	46	800	203	442	29.5	53.3	0.21	10.6	6.4	79.1	4.3	323	0.03	0.12	1.2	2.6

Table 3: Trace elements in flounder from the Hardanger Fjord and adjacent fjords (cont.).

Tabell 3. Sporelementinnhold i flyndre fra Hardangerfjorden og tilstøtende fjorder. (forts.)

Sex	Age (year)	Length (cm)	Weight (g)	Dry Substance gkg^{-1} F	Dry Substance gkg^{-1} L	As $mgkg^{-1}$ F	As $mgkg^{-1}$ L	Cu $mgkg^{-1}$ F	Cu $mgkg^{-1}$ L	Zn $mgkg^{-1}$ F	Zn $mgkg^{-1}$ L	Cd μgkg^{-1} F	Cd μgkg^{-1} L	Pb $mgkg^{-1}$ F	Pb $mgkg^{-1}$ L	Hg $mgkg^{-1}$ F	Hg $mgkg^{-1}$ L
Grimo																	
♀	5	33	330	216	475	13.7	10.1	0.30	5.9	3.8	74.3	1.8	60	0.01	0.10	0.35	0.39
♂	9	45	620	184	252	4.3	4.1	0.16	5.5	3.0	48.1	1.9	340	0.04	0.47	0.67	3.1
Eikhamrane																	
♂	4	30	180	192	416	57.1	50.8	0.70	3.0	3.2	21.3	2.6	1000	0.51	9.4	1.1	3.7
♂	5	33	200	179	481	235	i.b.	0.23	i.b.	1.8	i.b.	1.8	i.b.	0.06	i.b.	0.52	i.b.
♂	2	28	225	202	280	15.2	18.0	0.20	7.7	3.0	63.3	3.8	5240	0.14	5.6	0.40	5.2
♂	3	32	300	157	433	60.8	i.b.	0.50	i.b.	3.7	i.b.	2.9	i.b.	0.23	i.b.	0.39	i.b.
♀	5-6	36	300	175	227	128	115	0.19	1.7	2.9	25.6	3.6	590	0.33	6.3	1.3	5.6
♀	i.b.	30	350	210	416	5.2	9.5	0.22	3.1	4.5	37.5	3.1	840	0.08	0.55	0.06	0.06
♀	i.b.	32	360	217	370	36.9	31.3	0.69	6.5	3.6	49.6	1.9	780	0.06	0.66	0.20	1.1
♀	3	34	380	194	254	33.4	i.b.	0.65	i.b.	3.6	i.b.	3.9	i.b.	0.15	i.b.	0.63	i.b.
♀	i.b.	32	400	157	361	11.7	10.9	0.51	3.6	3.6	35.1	4.3	200	0.07	1.3	0.71	1.1
♂	i.b.	33	420	174	259	64.7	58.9	0.46	22.8	4.7	85.3	3.9	2900	0.14	3.4	0.38	13.7
♀	3	31	430	186	256	4.7	2.3	0.19	12.9	3.7	40.5	10.9	10500	0.02	2.3	0.11	0.68
♂	3	40	550	187	250	189	185	0.55	16.3	3.6	73.8	1.6	2180	0.07	4.5	0.24	0.55
♀	4	46	960	174	231	16.8	11.9	0.21	1.8	4.9	49.2	0.9	1680	0.26	0.47	0.10	0.14

Table 3: Trace elements in flounder from the Hardanger Fjord and adjacent fjords (cont.).

Tabell 3. Sporelementinnhold i flyndre fra Hardangerfjorden og tilstøtende fjorder. (forts.)

Sex	Age (year)	Length (cm)	Weight (g)	Dry Substance gkg^{-1}		As mgkg^{-1}		Cu mgkg^{-1}		Zn mgkg^{-1}		Cd µgkg^{-1}		Pb mgkg^{-1}		Hg mgkg^{-1}	
				F	L	F	L	F	L	F	L	F	L	F	L	F	L
Kråkevikneset																	
♂	2	23	107	182	175	16.2	i.b.	0.16	i.b.	5.0	i.b.	6.2	i.b.	0.11	i.b.	0.28	0.80
♂	3	26	110	207	220	10.5	i.b.	0.56	i.b.	12.9	i.b.	4.7	i.b.	0.59	i.b.	0.40	11.7
♂	2	24	120	196	100	119	i.b.	0.22	i.b.	4.4	i.b.	8.3	i.b.	1.0	i.b.	0.37	0.42
♂	2	25	158	173	167	32.0	i.b.	0.18	i.b.	3.5	i.b.	1.4	i.b.	0.12	i.b.	0.77	2.0
♀	2	26	163	175	i.b.	22.2	i.b.	0.18	i.b.	2.5	i.b.	1.8	i.b.	0.02	i.b.	0.26	i.b.
i.b.	i.b.	26	174	215	368	18.6	i.b.	0.20	i.b.	3.0	i.b.	1.0	i.b.	0.01	i.b.	0.58	i.b.
♂	3	25	187	191	289	9.2	9.7	0.48	4.4	4.9	i.b.	2.1	870	0.10	1.0	0.16	0.62
i.b.	i.b.	30	189	176	158	32.6	i.b.	0.19	i.b.	3.3	i.b.	1.1	i.b.	0.04	i.b.	0.76	0.82
i.b.	2	25	190	197	185	78.7	i.b.	0.20	i.b.	3.6	i.b.	4.0	i.b.	0.12	i.b.	0.24	i.b.
♂	2	25	200	201	292	12.6	7.7	0.50	4.3	15.3	27.4	6.6	820	0.19	2.3	0.18	0.49
♂	3	27	213	205	329	75.9	i.b.	0.17	i.b.	3.7	i.b.	3.6	i.b.	0.07	i.b.	0.53	i.b.
♂	4	34	219	168	222	40.0	i.b.	0.15	i.b.	4.5	i.b.	2.8	i.b.	0.18	i.b.	1.5	i.b.
♂	4	30	244	210	233	12.1	i.b.	0.20	i.b.	4.3	i.b.	1.3	i.b.	0.06	i.b.	0.50	i.b.
♀	2	30	308	206	156	1.4	3.4	0.22	0.88	6.4	11.7	9.7	136	0.20	0.07	0.03	0.07
i.b.	2-3	33	310	173	189	311	425	0.14	10.1	5.1	60.1	4.2	1680	0.20	2.6	0.48	0.42
♂	6	35	322	199	405	69.3	28.1	0.19	4.3	3.9	17.5	1.8	560	0.43	6.3	0.90	6.7
♂	5	40	482	166	233	100	402	0.15	15.4	2.8	80.8	2.2	3230	0.13	7.2	0.17	1.2
♀	i.b.	34	441	183	250	4.0	3.5	0.17	8.9	7.0	50.5	2.3	300	0.10	2.7	0.35	12.2
♀	3-4	35	533	216	263	47.3	42.3	0.17	13.9	4.3	42.2	1.9	1100	0.03	3.1	0.20	0.37
♀	i.b.	42	550	194	375	2.9	8.0	0.16	7.5	3.5	31.5	4.2	1470	0.01	0.25	0.09	0.25
♂	4	37	552	196	i.b.	97.0	i.b.	0.15	i.b.	3.1	i.b.	0.5	i.b.	0.05	i.b.	0.14	i.b.
♂	8	47	655	169	198	19.2	26.7	0.18	1.8	2.7	20.9	1.8	660	0.04	0.33	2.4	i.b.

TEXT FOR FIGURES 1-20

Fig. 1. Sampling Locations for Natural and Bred Common Mussels in the Hardanger fjord and Adjacent Fjords.

Fig. 2. Sampling Locations for Pollack and Flounder in the Hardanger Fjord and Adjacent Fjords.

Fig. 3. The Arsenic Content in Natural and Bred Common Mussels ($mgkg^{-1}$, fresh weight) from the Hardanger Fjord and Adjacent Fjords with Bars Representing Concentrations.

Fig. 4. Copper Content in Natural and Bred Common Mussels ($mgkg^{-1}$, fresh weight) from the Hardanger Ford and Adjacent Fjords with Bars Representing Concentrations.

Fig. 5. Zinc Content in Natural and Bred Common Mussels ($mgkg^{-1}$, fresh weight), from the Hardanger Fjord and Adjacent Fjords with Bars Representing Concentrations.

Fig. 6. Cadmium Content in Natural and Bred Common Mussels ($mgkg^{-1}$, fresh weight) from the Hardanger fjord and Adjacent Fjords with Bars Representing Concentrations.

Fig. 7. Lead Content in Natural and Bred Common Mussels ($mgkg^{-1}$, fresh weight), from the Hardanger Fjord and Adjacent Fjords with Bars Representing Concentrations.

Fig. 8. Mercury Content in Natural and Bred Common Mussels ($mgkg^{-1}$, fresh weight), from the Hardanger Fjord and Adjacent Fjords with Bars Representing Concentrations.

Fig. 9. Mean Arsenic Content in Fillets and Liver from Pollack ($mgkg^{-1}$, fresh weight), Caught in the Hardanger Fjord and Adjacent Fjords with Bars Representing Concentrations.

Fig. 10. Mean Arsenic Content in Fillets and Liver from Flounder ($mgkg^{-1}$, fresh weight), Caught in the Hardanger Fjord and Adjacent Fjords with Bars Representing Concentrations.

Fig. 11. Mean Copper Content in Fillets and Liver from Pollack ($mgkg^{-1}$, fresh weight), Caught in the Hardanger Fjord and Adjacent Fjords with Bars Representing Concentrations.

Fig. 12. Mean Copper Content in Fillets and Livers from Flounder ($mgkg^{-1}$, fresh weight), Caught in the Hardanger Fjord and Adjacent Fjords with Bars Representing Concentrations.

Fig. 13. Mean Zinc Content in Fillets and Liver from Pollack ($mgkg^{-1}$, fresh weight), Caught in the Hardanger Fjord and Adjacent Fjords with Bars Representing Concentrations.

Fig. 14. Mean Zinc Content in Fillets and Liver from Flounder ($mgkg^{-1}$, fresh weight), Caught in the Hardanger Fjord and Adjacent Fjords with Bars Representing Concentrations. Fig 15.

Mean Cadmium Content in Fillets and Liver from Pollack ($mgkg^{-1}$, fresh weight), Caught in the Hardanger Fjord and Adjacent Fjords with Bars Representing Concentrations.

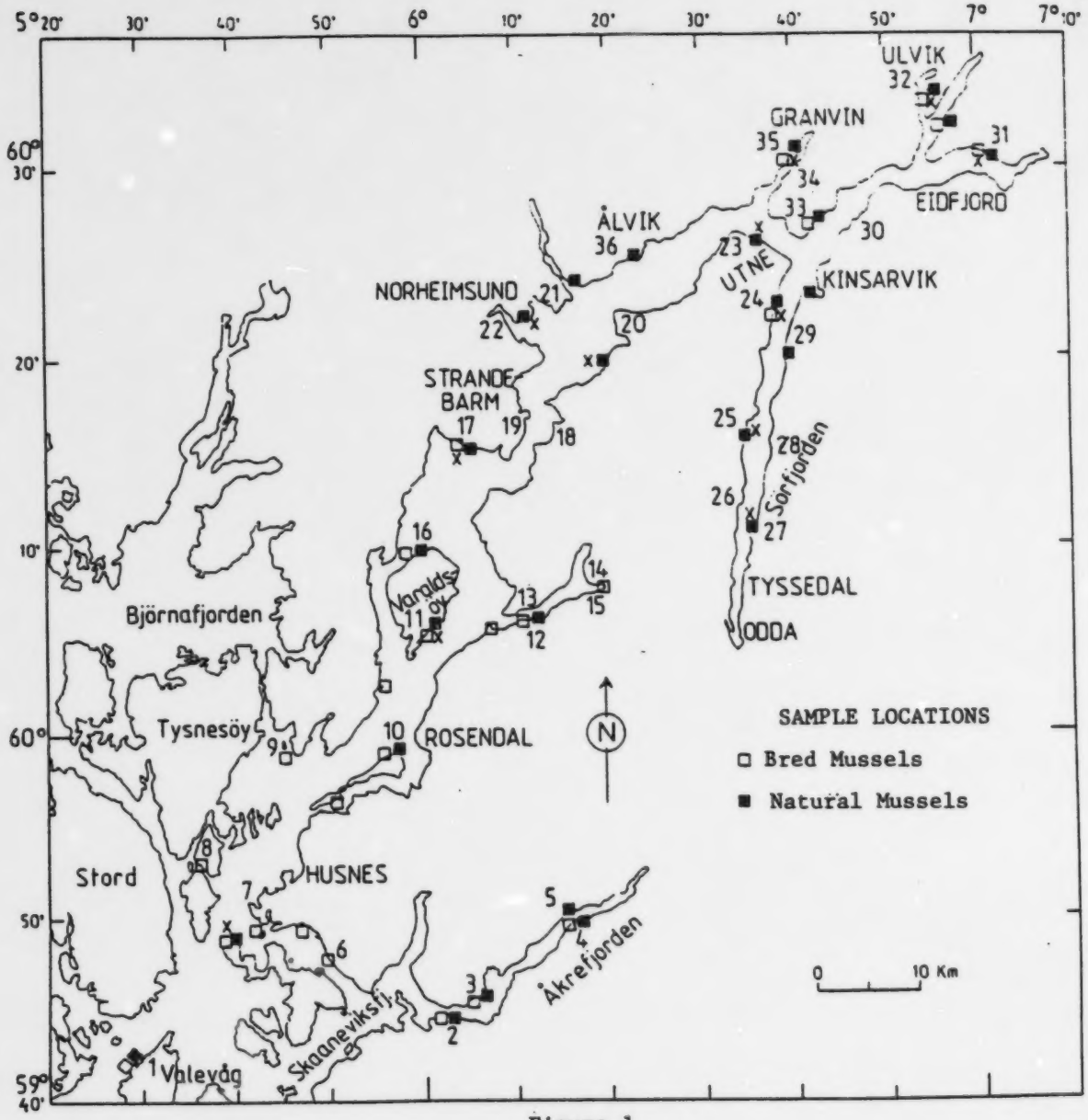
Fig. 16. Mean Cadmium Content in Fillets and Liver from Flounder ($mgkg^{-1}$, fresh weight), Caught in the Hardanger Fjord and Adjacent Fjords with Bars Representing Concentrations.

Fig. 17. Mean Lead Content in Fillets and Liver from Pollack ($mgkg^{-1}$, fresh weight), Caught in the Hardanger Fjord and Adjacent Fjords with Bars Representing Concentrations.

Fig. 18. Mean Lead Content in Fillets and Liver from Flounder ($mgkg^{-1}$, fresh weight), Caught in the Hardanger Fjord and Adjacent Fjords with Bars Representing Concentrations.

Fig. 19. Mean Mercury Content in Fillets and Liver from Pollack ($mgkg^{-1}$, fresh weight), Caught in the Hardanger Fjord and Adjacent Fjords with Bars Representing Concentrations.

Fig. 20. Mean Mercury Content in Fillets and Liver from Flounder ($mgkg^{-1}$, fresh weight), Caught in the Hardanger Fjord and Adjacent Fjords with Bars Representing Concentrations.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GRANVIN
35
31
34
33
EIDFJORD
30
ÅLVIK
36
23
UTNE
KINSARVIK
24
NORHEIMSUND
21
22
20
29
STRANDE
BARM
17
19
18
25
28
Sørfjorden
26
27
16
TYSSEDAL
14
Varaldsøy
11
13
15
12
ODDA
Björnafjorden
Tysnesöy
9
10
ROSENDAL
N
SAMPLE LOCATIONS
Bred Mussels
Natural Mussels
8
Stord
7
HUSNES
5
6
3
Åkrefjorden
0
10 Km
2
1 Valevåg
Skånevikfj.
5°20'
30'
40'
50'
6°
10'
20'
30'
40'
50'
7°
7°10'
60°30'
20'
10'
60°
50'
59°40'

Figure 1

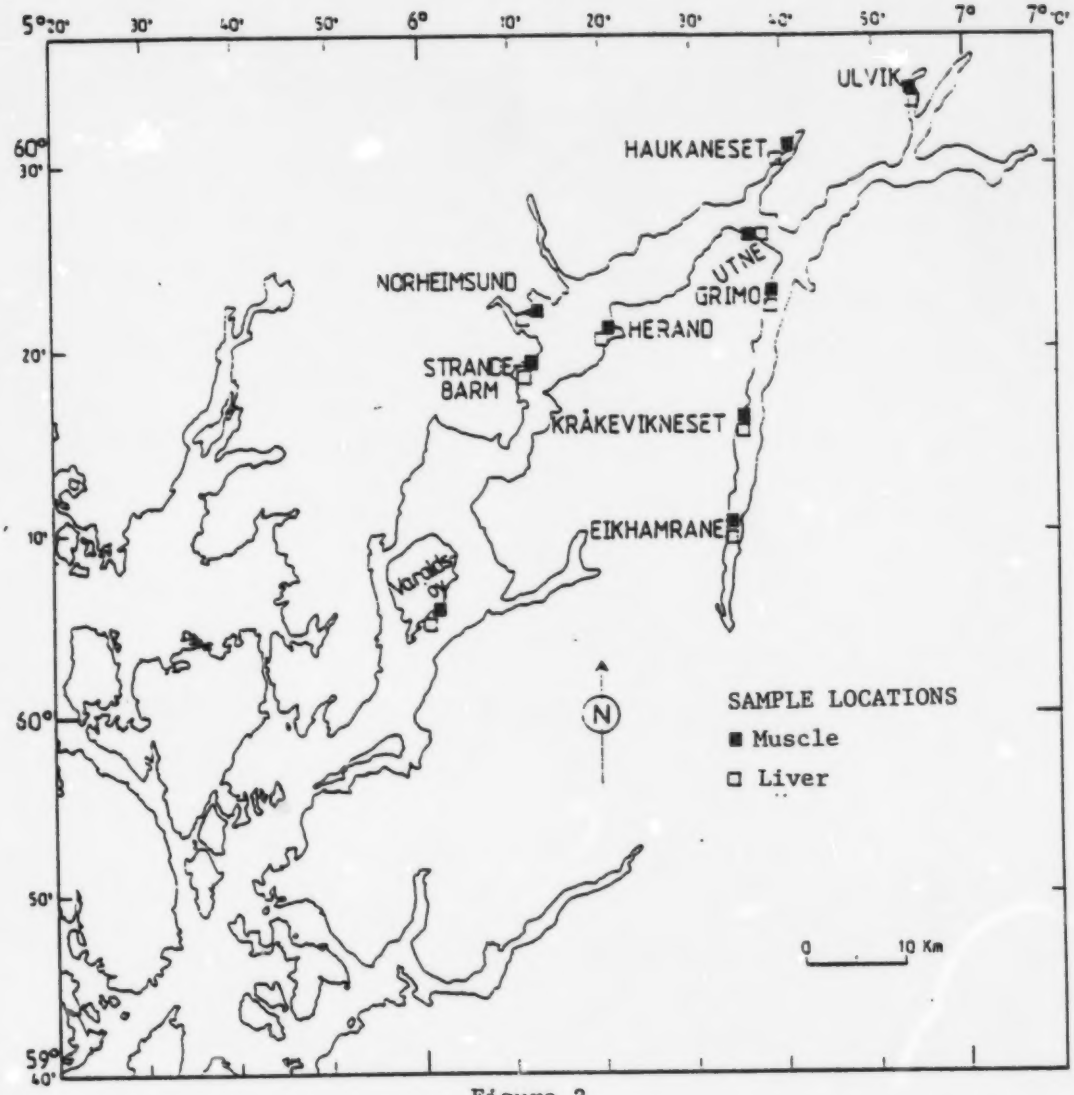
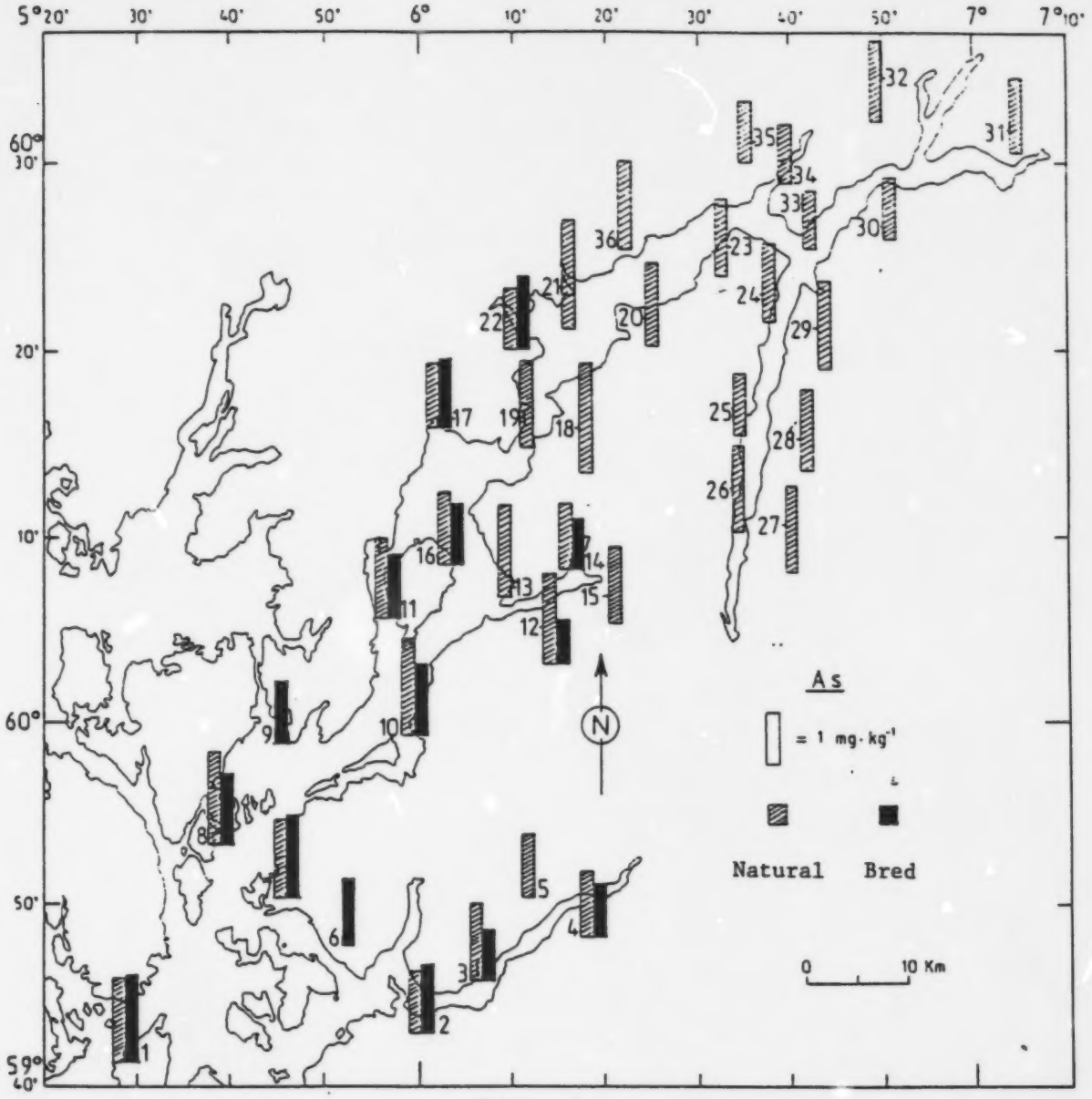

ULVIK
HAUKANESET
UTNE
GRIMO
NORHEIMSUND
HERAND
STRANDE
BARM
KRÅKEVIKNESET
EIKHAMRANE
Varaldsøy
N
SAMPLE LOCATIONS
Muscle
Liver
0
10 Km

Figure 2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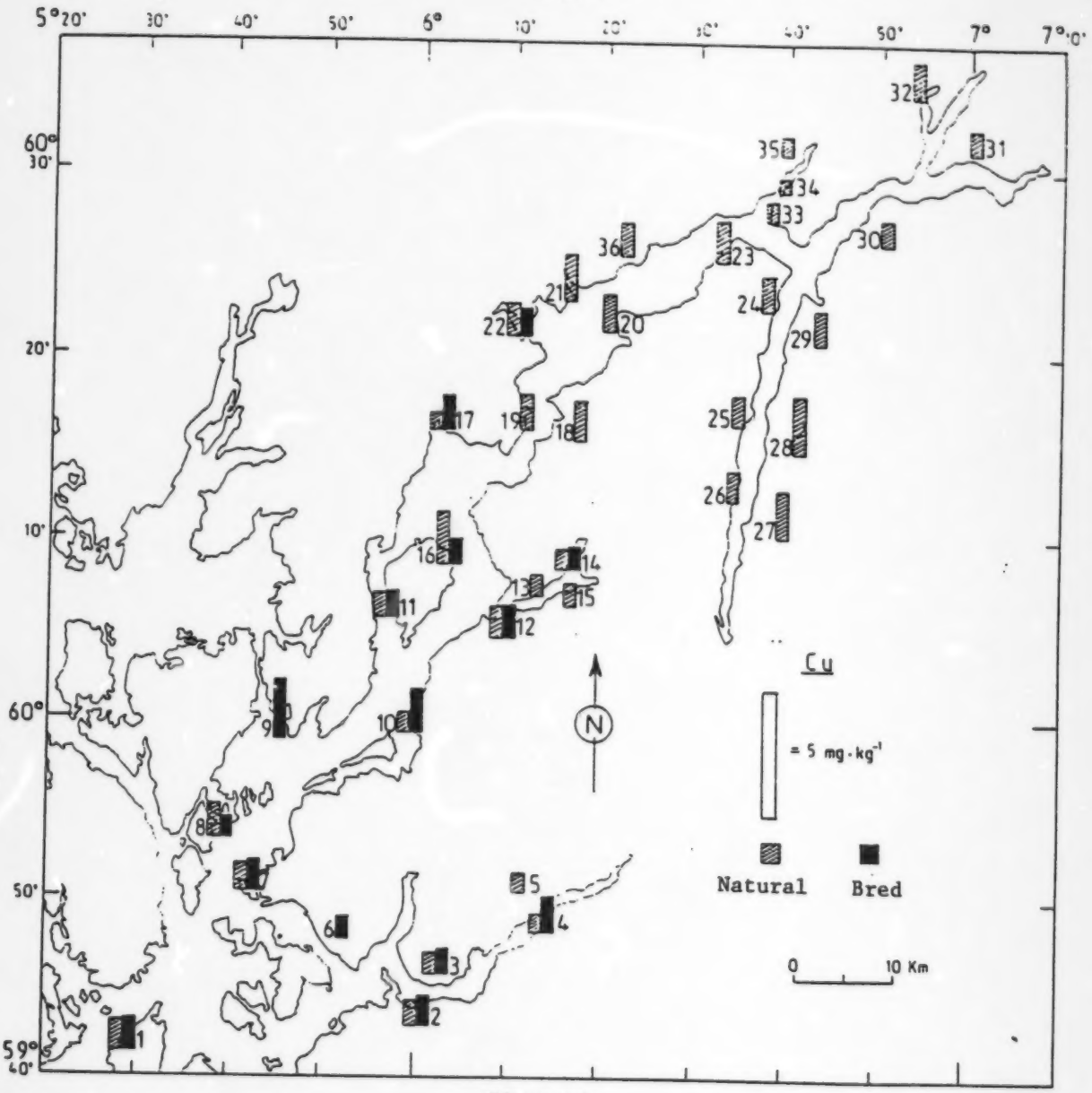
50'
6°
10'
20'
30'
40'
50'
7°
7°10'
60°30'
20'
10'
60°
50'
59°40'
As
= 1 mg·kg⁻¹
Natural
Bred
N
0
10 Km

Figure 3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30'
40'
50'
6°
10'
20'
30'
40'
50'
7°
7°10'
60°30'
20'
10'
60°
50'
59°40'
Cu
= 5 mg·kg⁻¹
Natural
Bred
N
0
10 Km

Figure 4

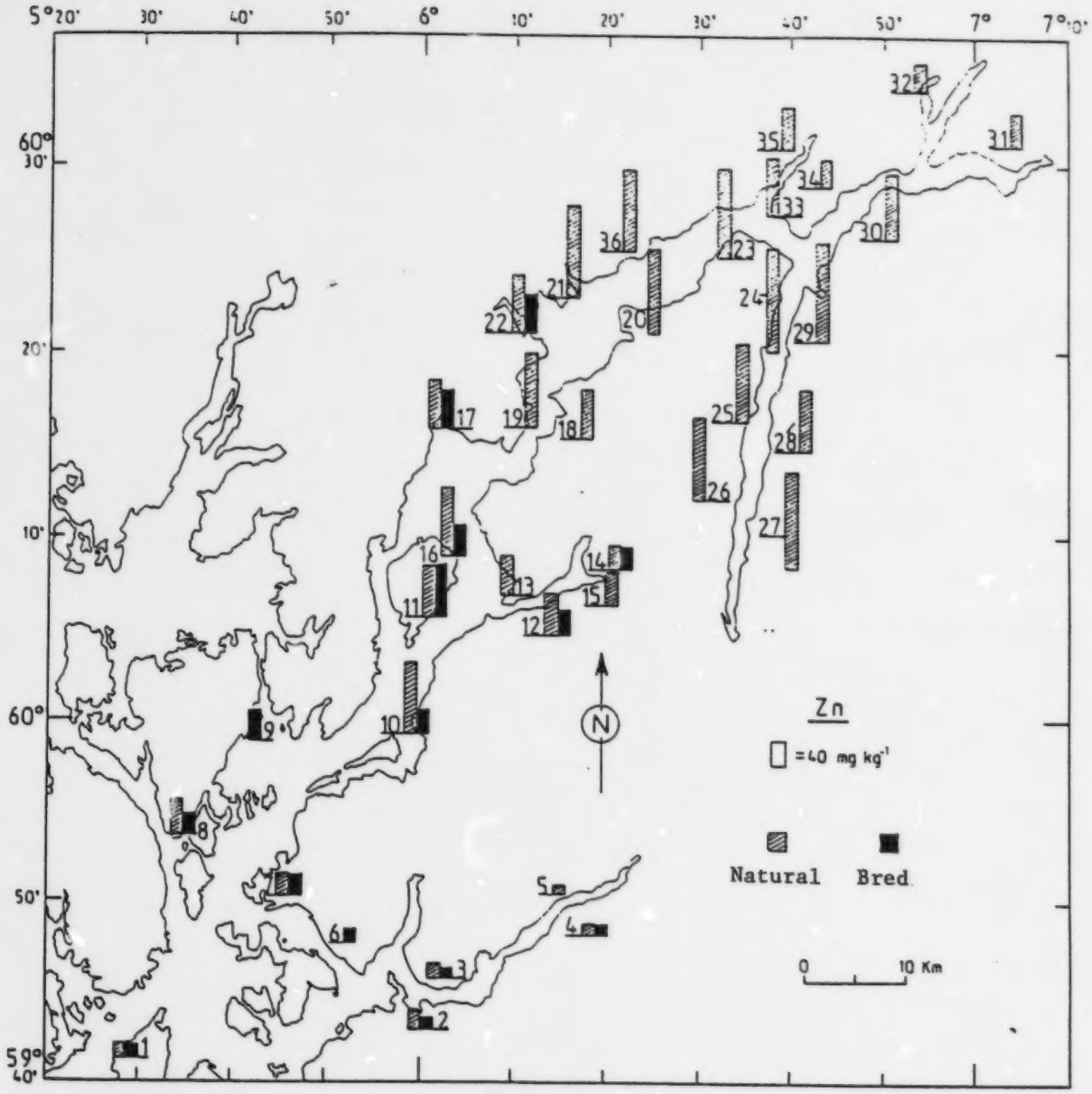
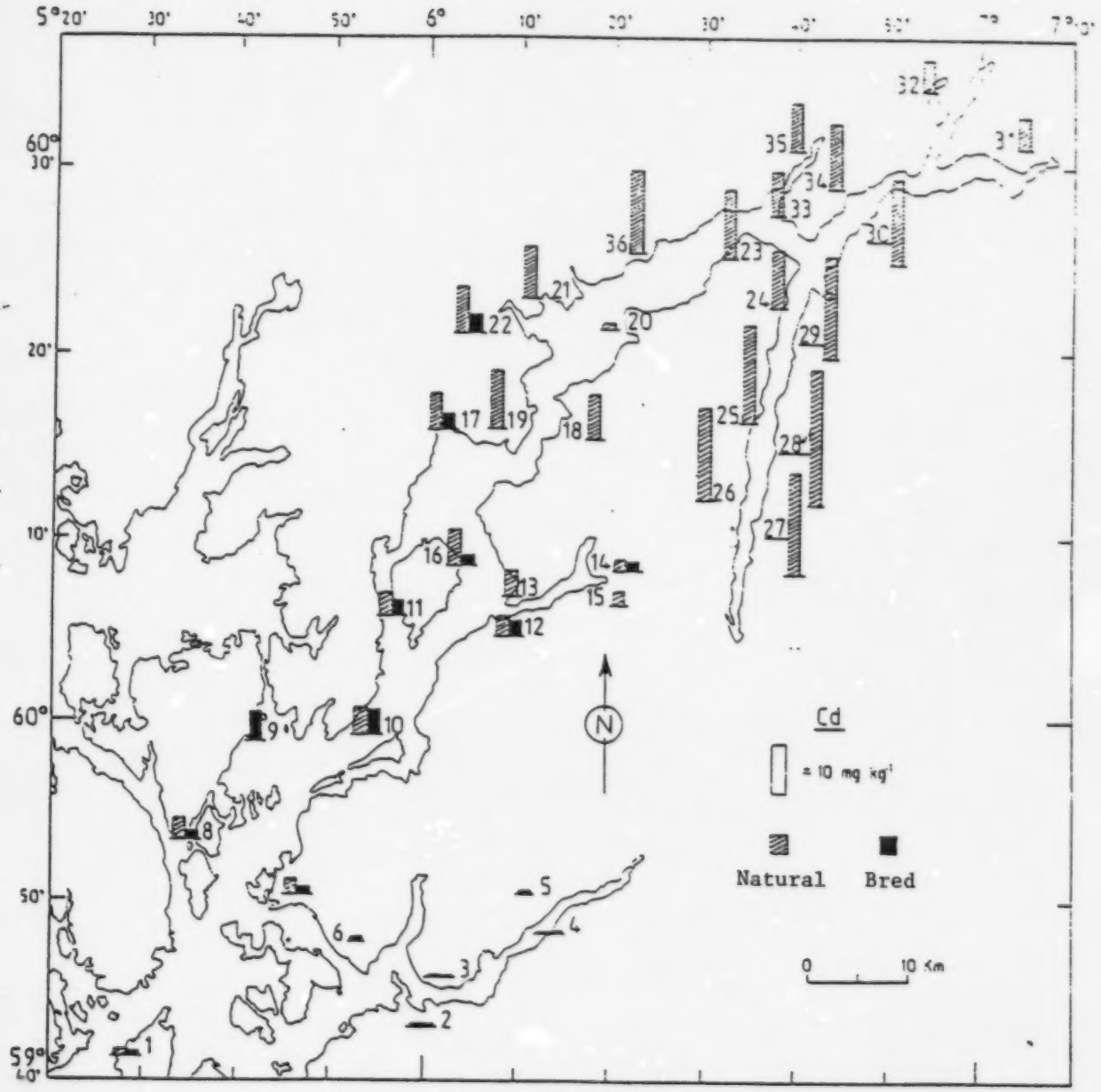

5°
20'
30'
40'
50'
6°
10'
20'
30'
40'
50'
7°
7°10'
60°30'
20'
10'
60°
50'
59°40'
Zn
=40 mg kg⁻¹
Natural
Bred
N
0
10 Km

Figure 5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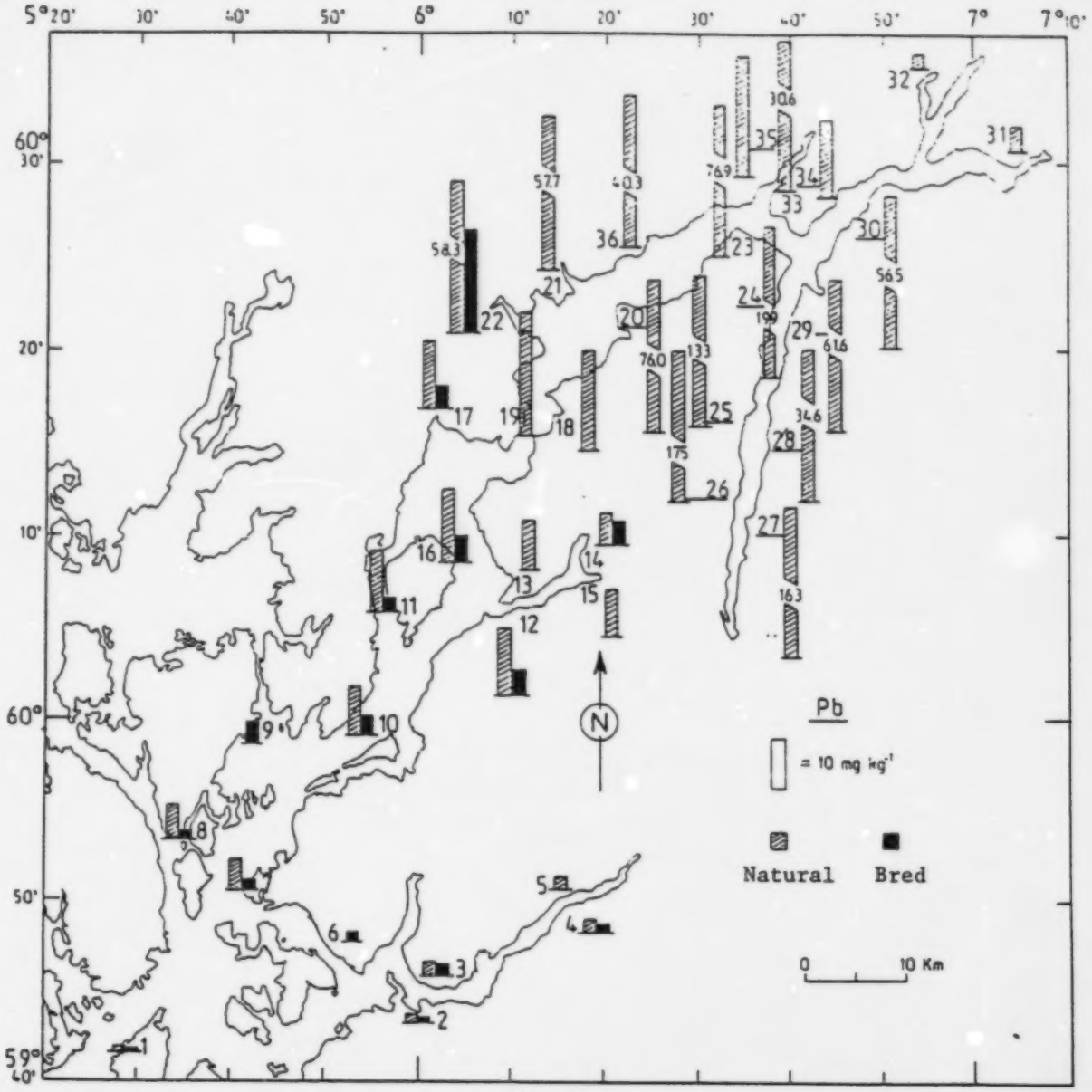
30'
40'
50'
6°
10'
20'
30'
60°30'
20'
10'
60°
50'
59°40'
N
Cd
= 10 mg kg⁻¹
Natural
Bred
0
10 Km

Figure 6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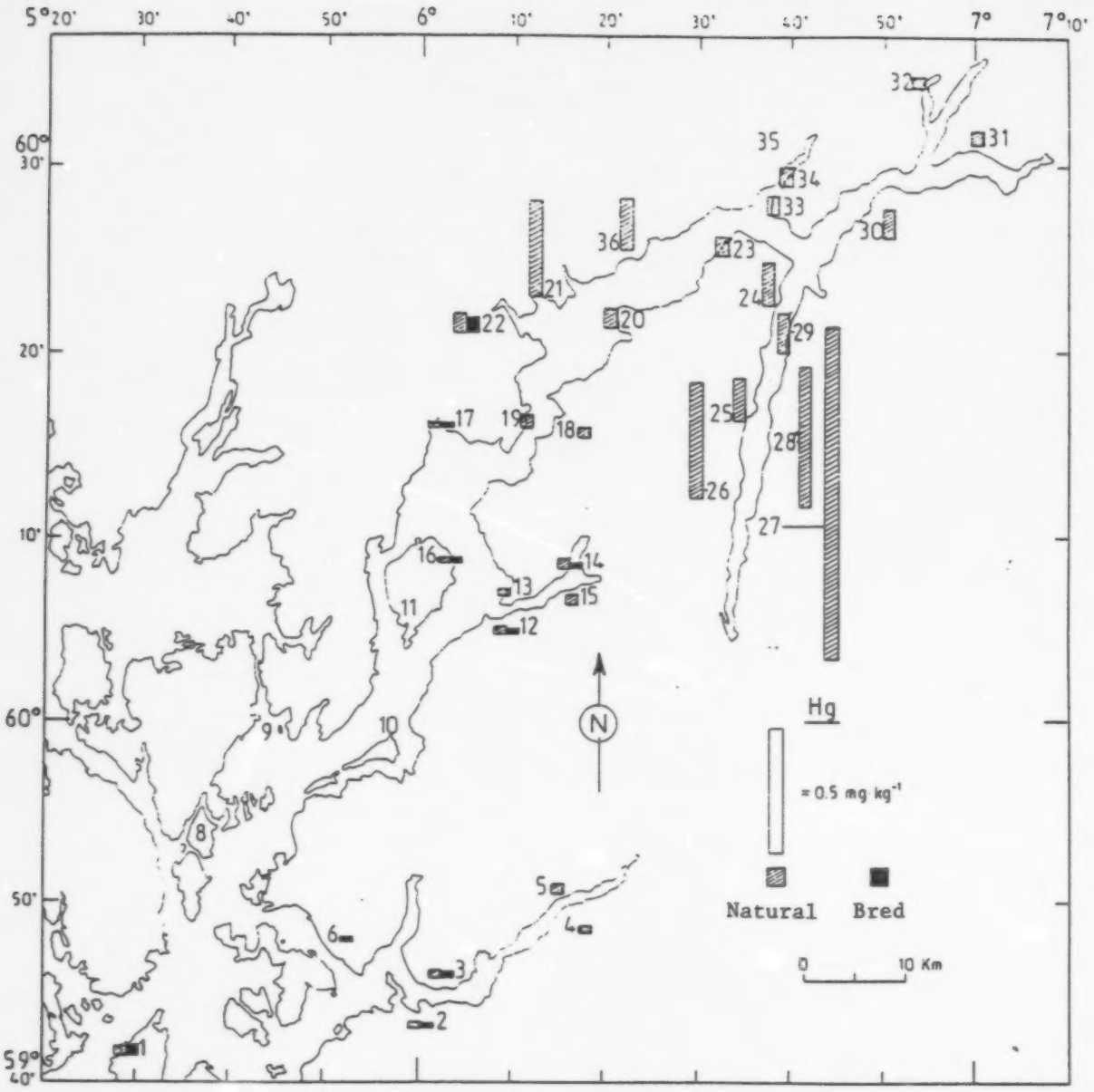
50'
6°
10'
20'
30'
40'
50'
7°
7°10'
60°30'
20'
10'
60°
50'
59°40'
32
30.6
31
35
34
33
30
56.5
36
57.7
40.3
76.9
23
24
19.9
29
61.6
58.3
22
21
20
76.0
13.3
25
34.6
28
17
19
18
17.5
26
27
16
14
13
15
16.3
11
12
10
9
N
Pb
= 10 mg kg⁻¹
Natural
Bred
8
5
4
6
3
2
1
0
10 Km

Figure 7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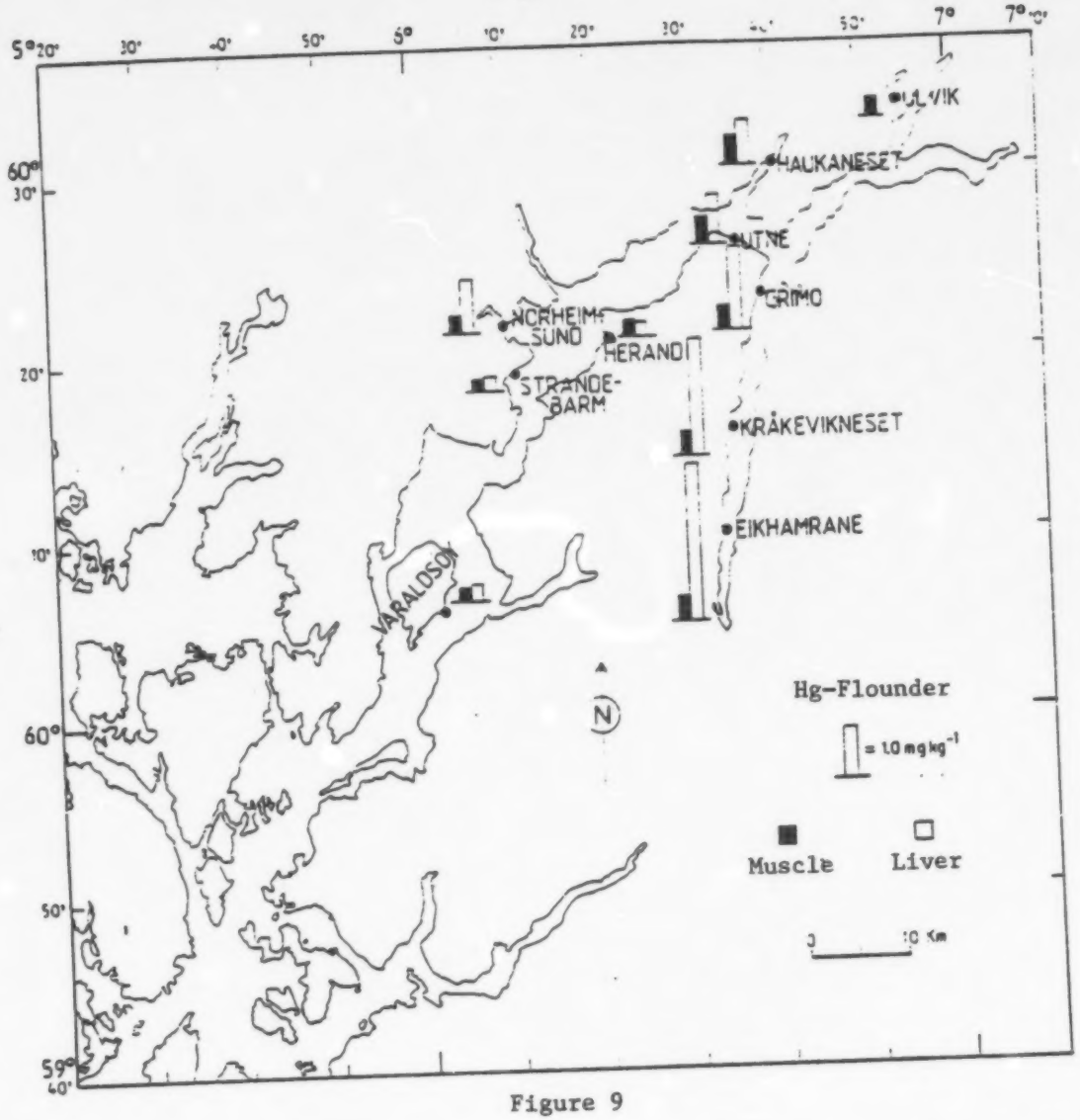
7°
7°10'
60°30'
20'
10'
60°
50'
59°40'
1
2
3
4
5
6
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
N
Hg
= 0.5 mg kg⁻¹
Natural
Bred
0
10 Km

Figure 8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HAUKANESET
VITNE
GRIMO
NORHEIMSUND
HERAND
STRANDEBARM
KRÅKEVIKNESET
EIKHAMRANE
VARALDSØY
Hg-Flounder
= 1.0 mg kg⁻¹
Muscle
Liver
N
60°
59°
10°
20°
30°
50°
5°
7°

Figure 9

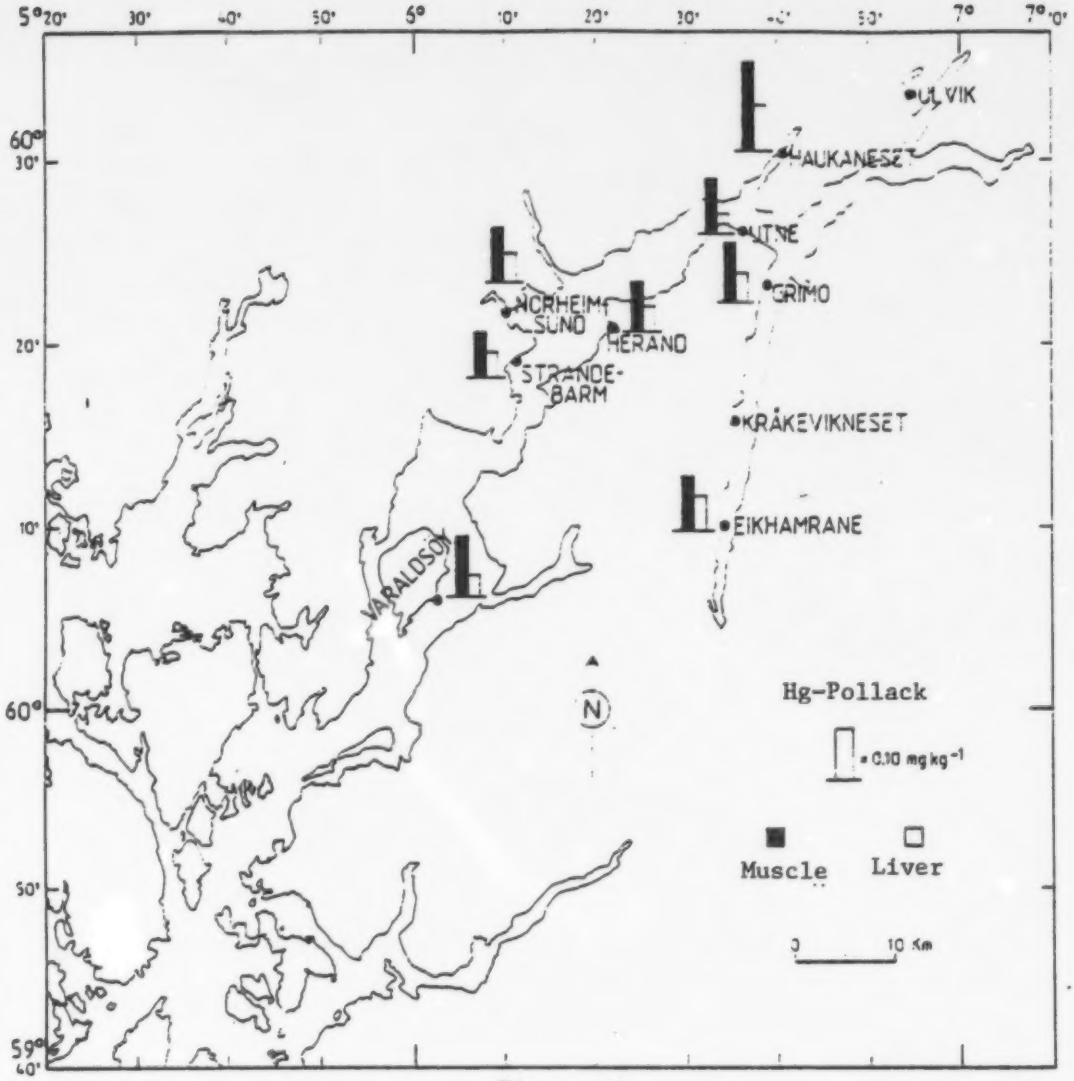
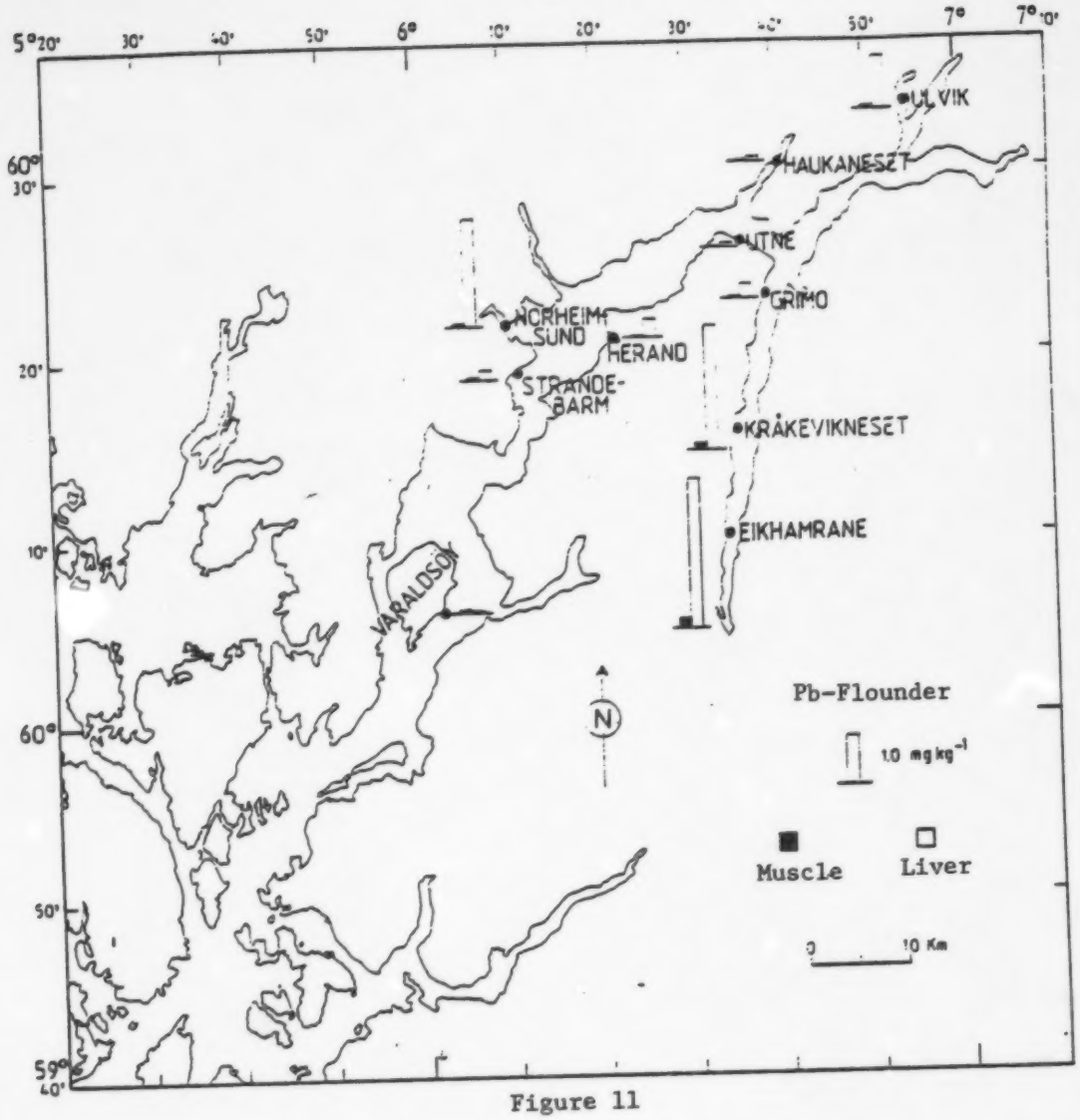

ULVIK
HAUKANESET
UTNE
GRIMO
NORHEIMSUND
HERAND
STRANDEBARM
KRÅKEVIKNESET
EIKHAMRANE
VARALDSØY
N
Hg-Pollack
0.10 mg kg⁻¹
Muscle
Liver
10 km

Figure 10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7°10'
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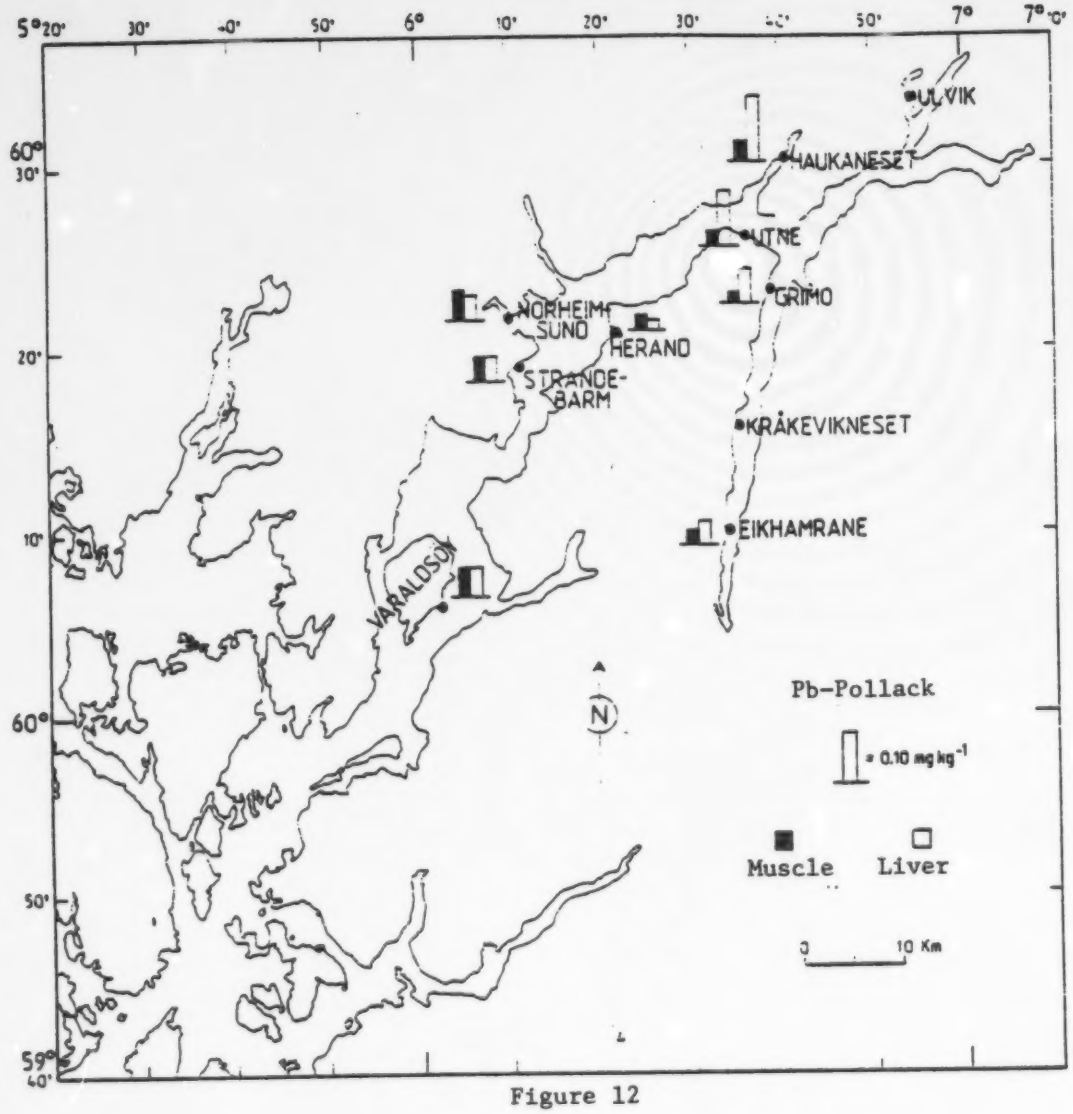
20'
10'
60°
50'
59°40'
LILLVIK
HAUKANESET
UTNE
GRIMO
NORHEIM-SUND
HERAND
STRANDE-BARM
KRÅKEVIKNESET
EIKHAMRANE
VARALDSØY
N
Pb-Flounder
1.0 mg kg⁻¹
Muscle
Liver
0
10 Km

Figure 11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7°10'
60°30'
20'
10'
60°
50'
59°40'
ULVIK
HAUKANESET
UTNE
GRIMO
NORHEIM
SUND
HERAND
STRANDE-
BARM
KRÅKEVIKNESET
EIKHAMRANE
VARALDSØY
N
Pb-Pollack
= 0.10 mg kg⁻¹
Muscle
Liver
0
10 Km

Figure 12

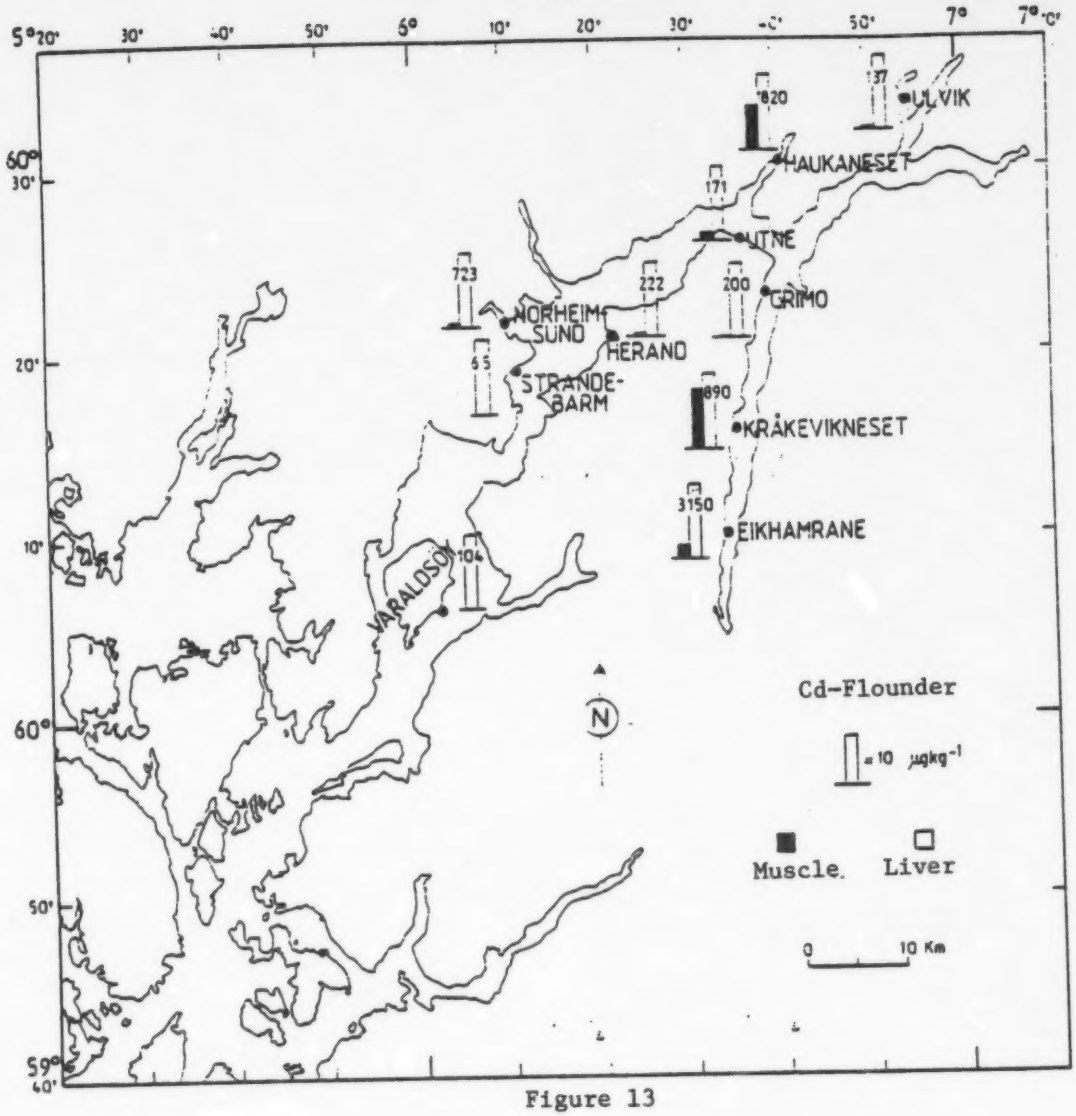

820
37
ULVIK
HAUKANESET
171
UTNE
723
222
200
GRIMO
NORHEIM SUND
HERAND
65
STRANDE-BARM
890
KRÅKEVIKNESET
3150
EIKHAMRANE
104
VARALDSØY
N
Cd-Flounder
= 10 µgkg⁻¹
Muscle
Liver
0
10 Km

Figure 13

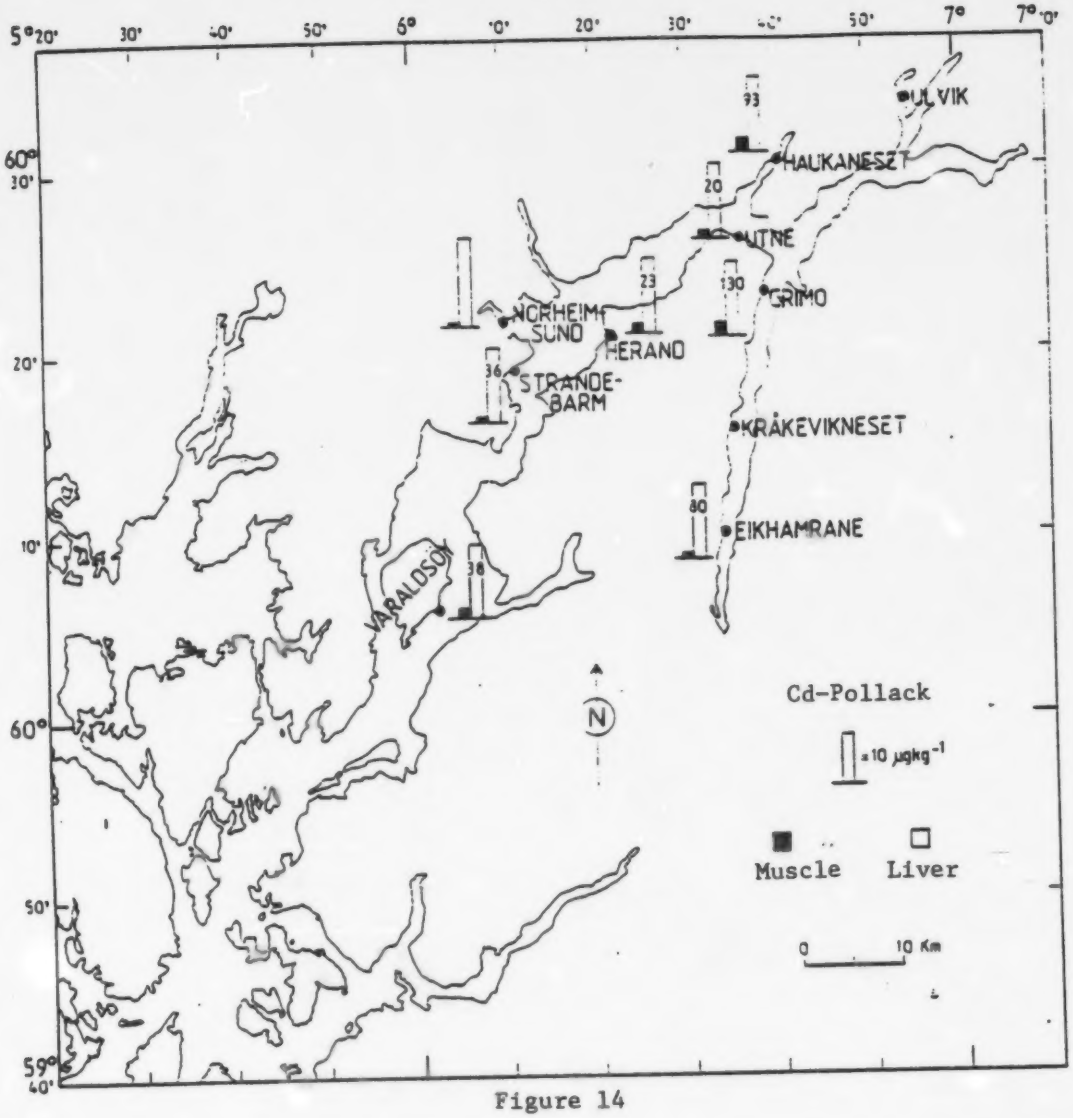

ULVIK
HAUKANESET
UTNE
GRIMO
NORHEIMSUND
HERAND
STRANDEBARM
KRÅKEVIKNESET
EIKHAMRANE
VARALDSØY
93
20
23
130
36
80
38
N
Cd-Pollack
= 10 µgkg⁻¹
Muscle
Liver
0
10 Km

Figure 14

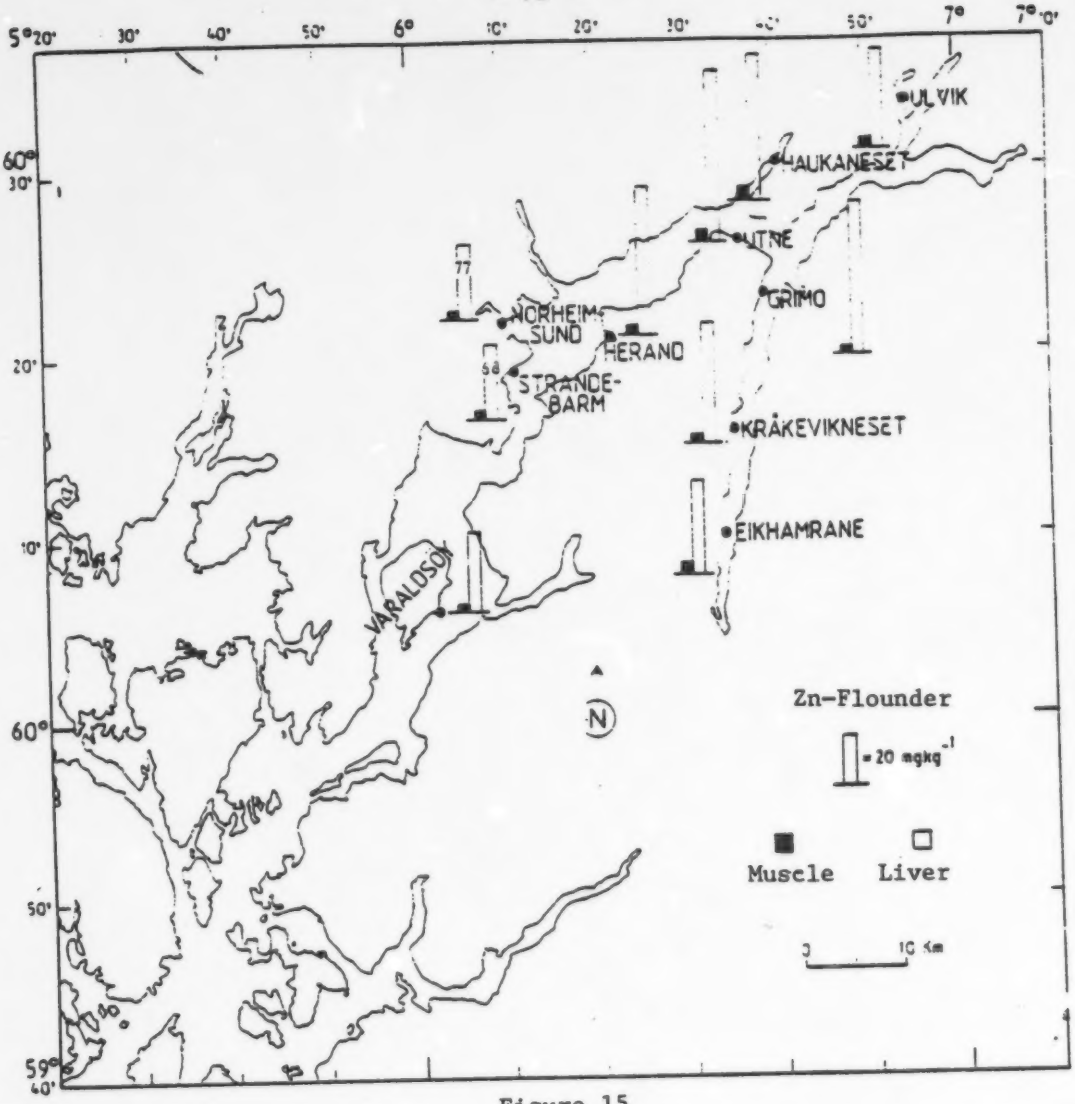
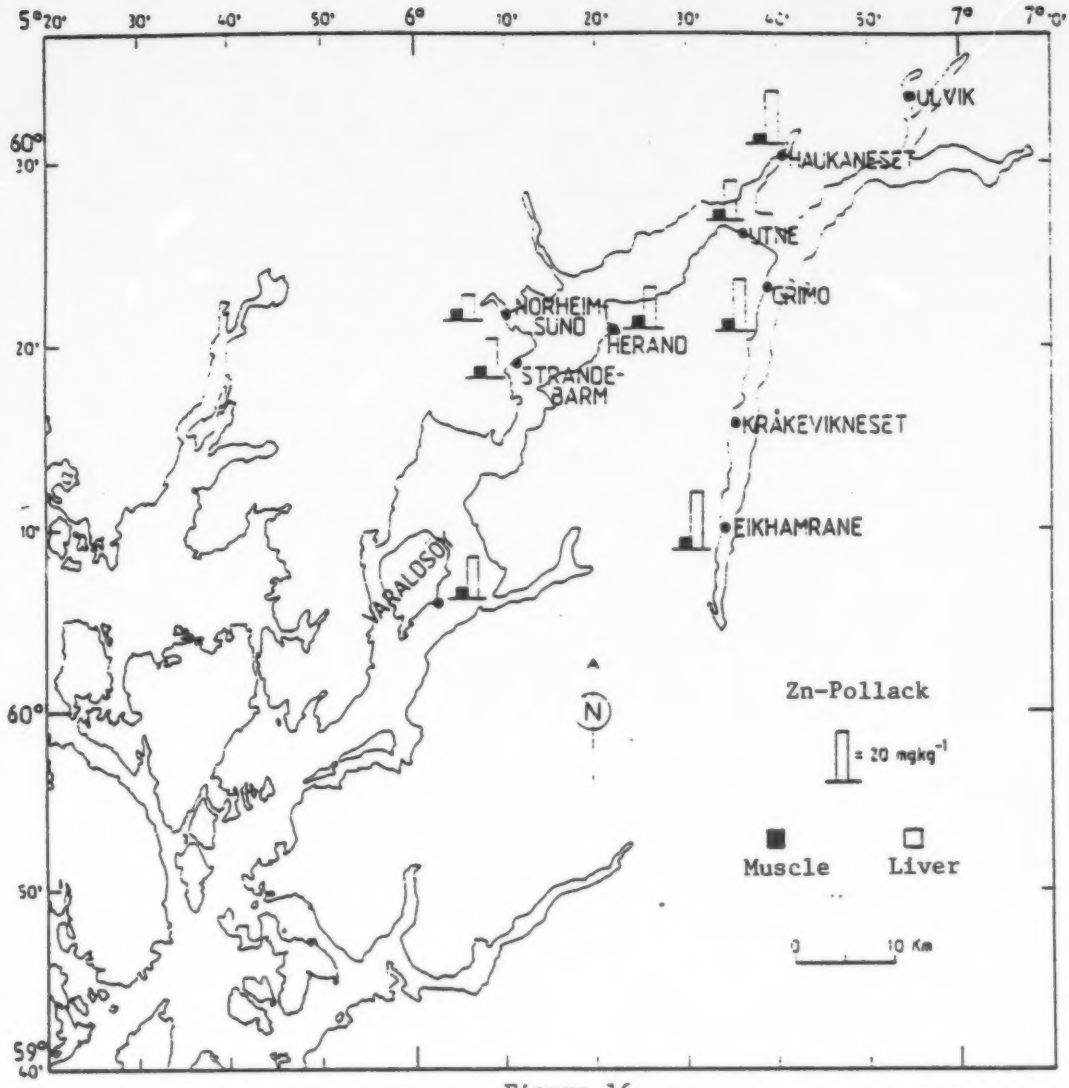

ULVIK
HAUKANESET
UTNE
GRIMO
NORHEIM-SUND
HERAND
STRANDE-BARM
KRÅKEVIKNESET
EIKHAMRANE
VARALDSØY
N
Zn-Flounder
= 20 mgkg⁻¹
Muscle
Liver
10 km

Figure 15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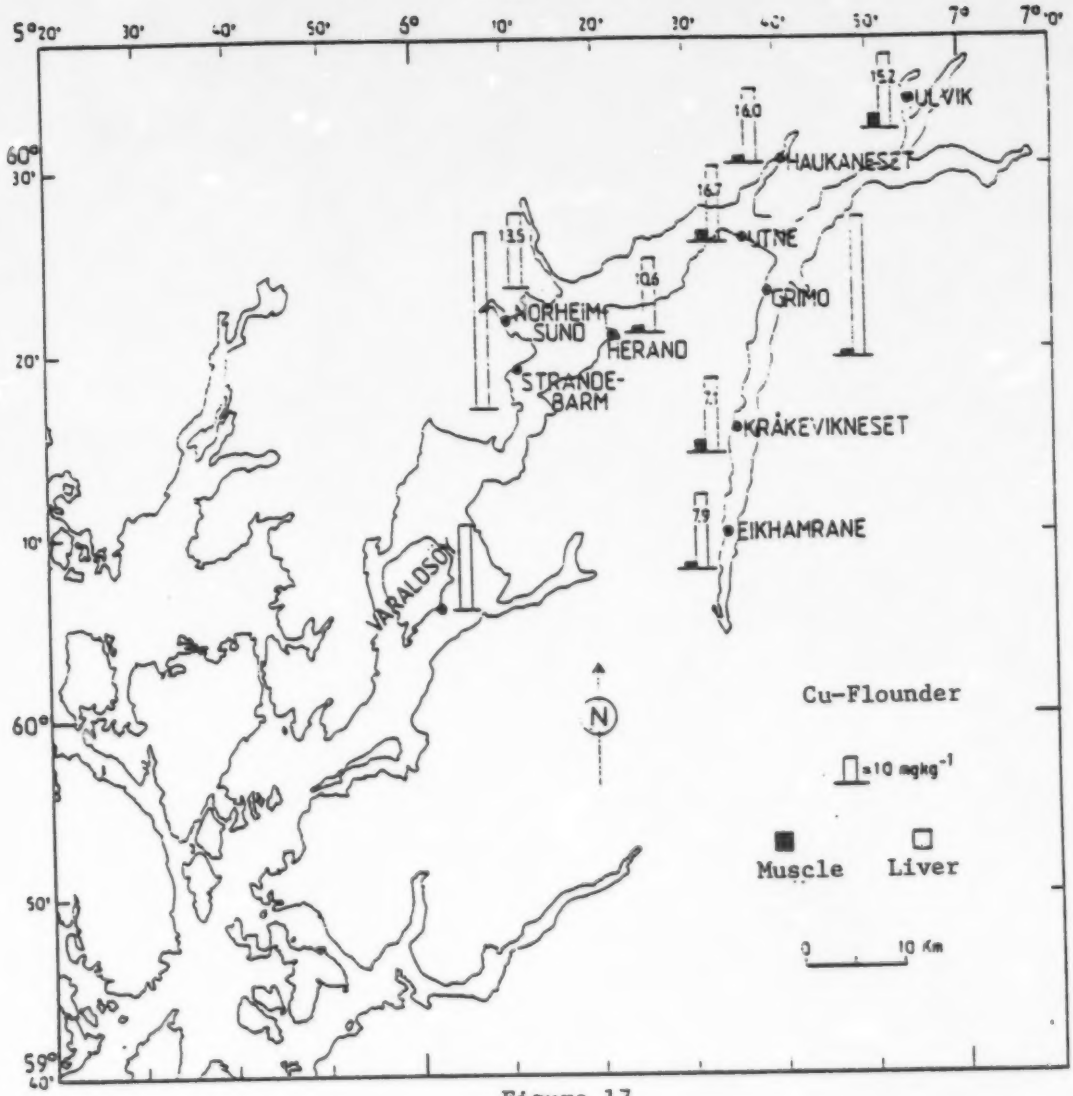
40'
50'
6°
10'
20'
30'
40'
50'
7°
7°10'
60°30'
20'
10'
60°
50'
59°40'
ULVIK
HAUKANESET
UTNE
GRIMO
NORHEIM SUND
HERAND
STRANDE-BARM
KRÅKEVIKNESET
EIKHAMRANE
VARALDSØY
N
Zn-Pollack
= 20 mgkg⁻¹
Muscle
Liver
0
10 Km

Figure 16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6°
10'
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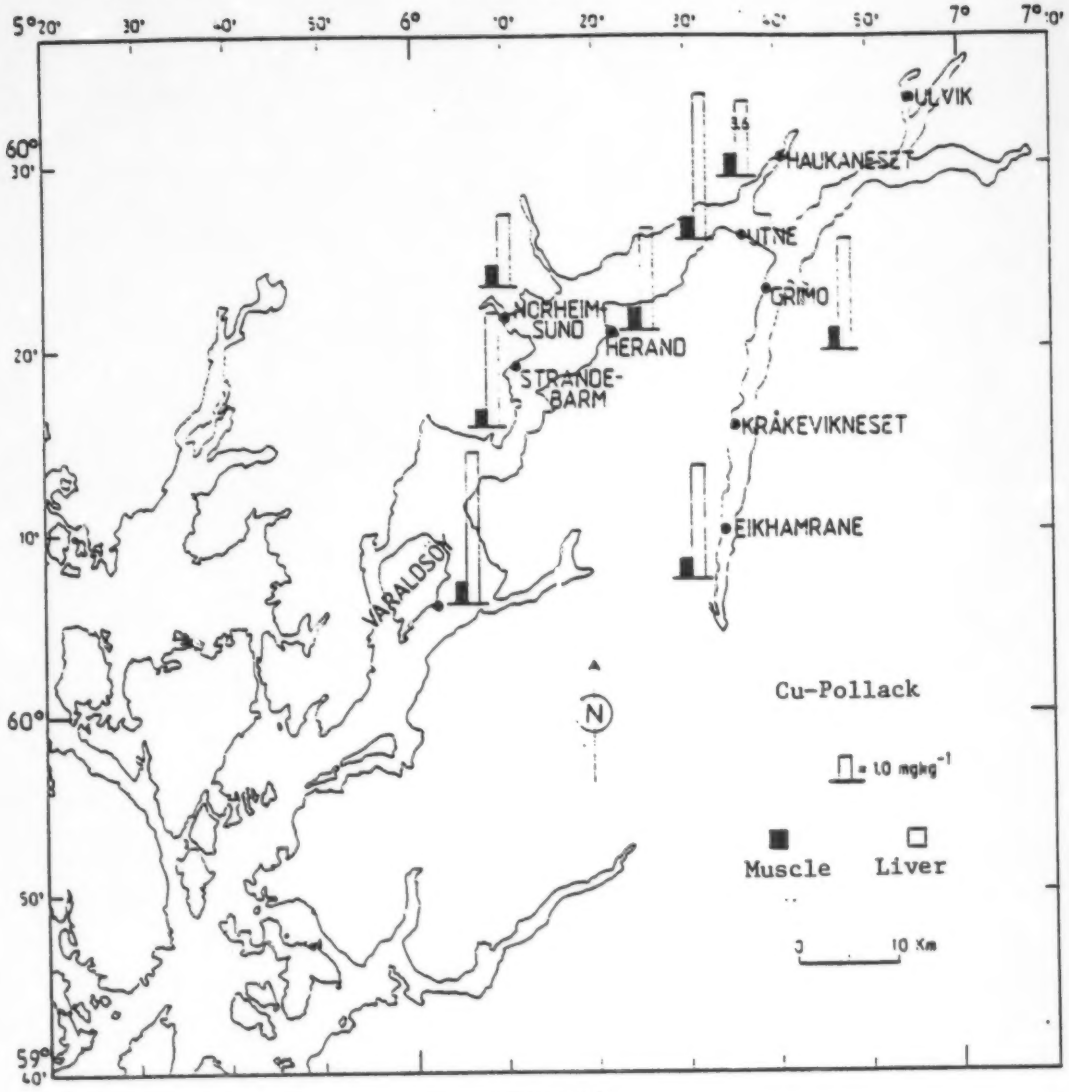
30'
40'
50'
7°
7°10'
60°30'
20'
10'
60°
50'
59°40'
15.2
ULVIK
16.0
HAUKANESET
16.7
UTNE
13.5
10.6
GRIMO
NORHEIM-SUND
HERAND
STRANDE-FJORD
KRÅKEVIKNESET
7.9
EIKHAMRANE
VARALDSØY
N
Cu-Flounder
≙10 mgkg⁻¹
Muscle
Liver
0
10 Km

Figure 17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50'
6°
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20'
30'
40'
50'
7°
7°10'
60°30'
20'
10'
60°
50'
59°40'
ULVIK
3.6
HAUKANESET
UTNE
GRIMO
NORHEIM-SUND
HERAND
STRANDE-BARM
KRÅKEVIKNESET
EIKHAMRANE
VARALDSØY
N
Cu-Pollack
= 10 mgkg⁻¹
Muscle
Liver
0
10 Km

Figure 18

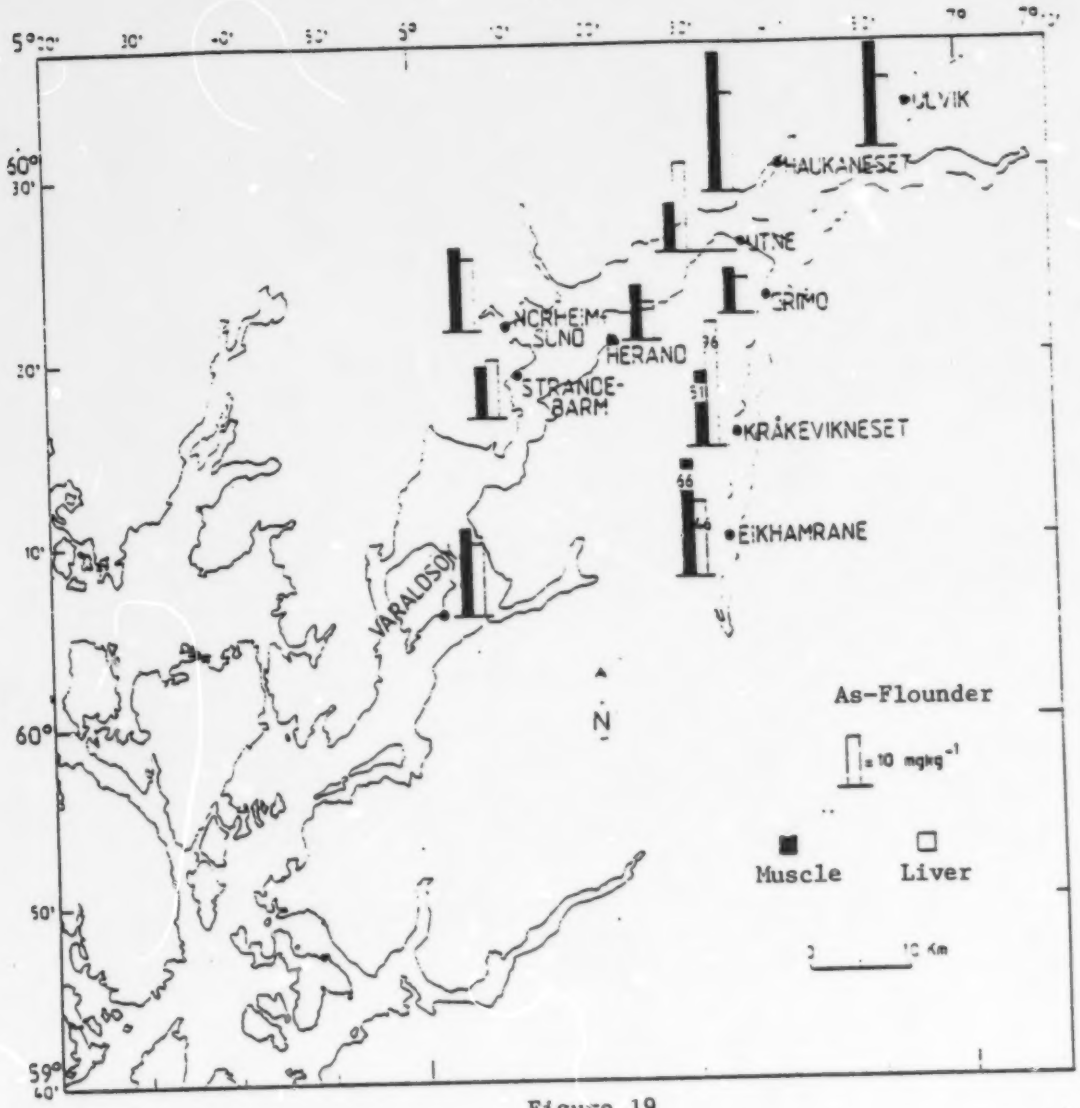
HAUKANESET
UTNE
GRIMO
NORHEIM-SUND
HERAND
STRANDE-BARM
KRÅKEVIKNESET
EIKHAMRANE
VARALDSØY
N
As-Flounder
= 10 mgkg⁻¹
Muscle
Liver

Figure 19

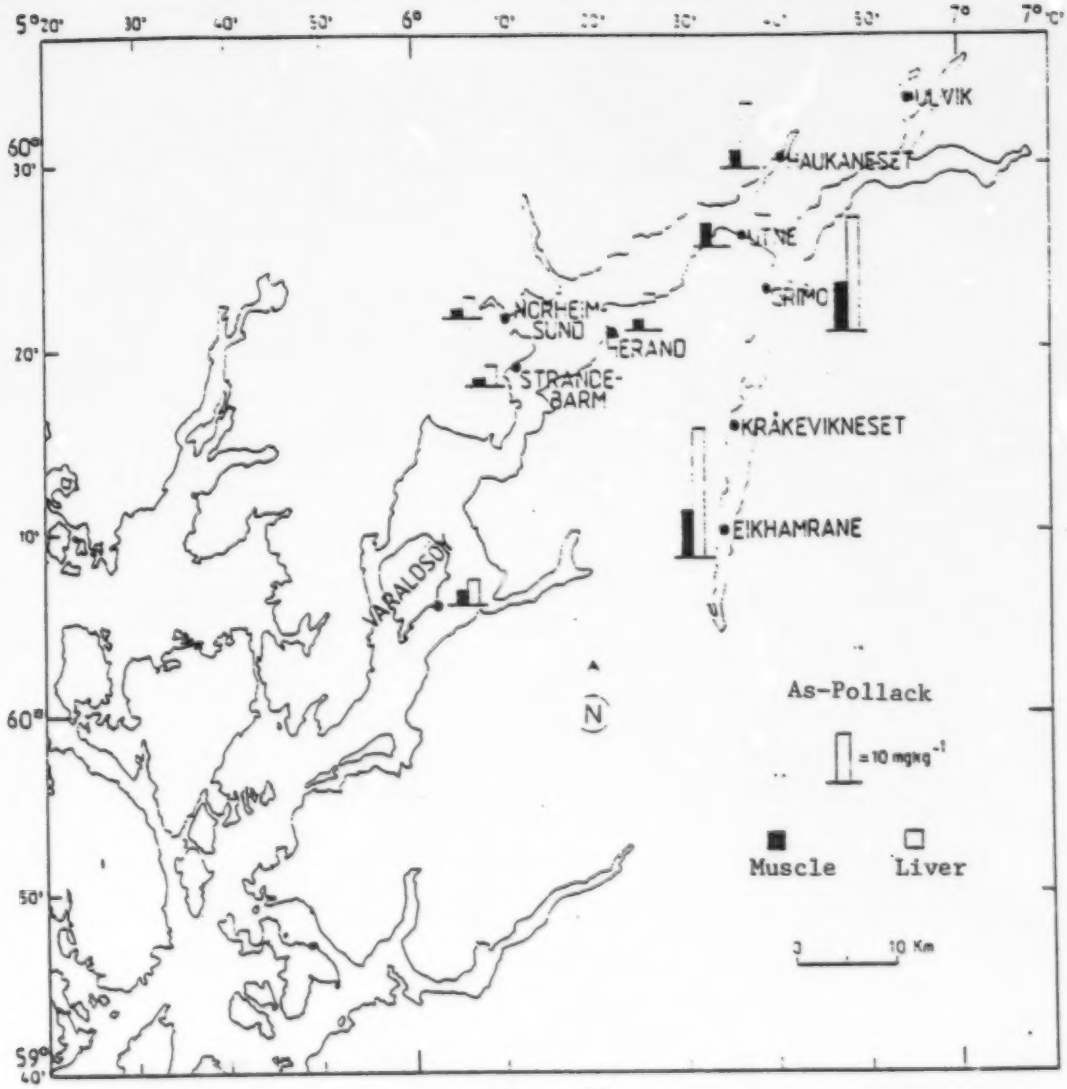
ALVIK
AUKANESET
GRIMO
NORHEIM-SUND
HERAND
STRANDE-BARM
KRÅKEVIKNESET
EIKHAMRANE
VARALDSØY
N
As-Pollack
= 10 mgkg⁻¹
Muscle
Liver
10 Km

Figure 20